(2)

WL-TR-91-4140

AD-A264 470

LONG-TERM TROPIC ENVIRONMENTAL EXPOSURE OF ARMY STANDARD FAMILY (ASF) RIGID WALL HONEYCOMB SANDWICH PANELS

WRIGHT LABORATORY

David A. Mikelson
U.S. Army Natick Research, Development, and Engineering Center (NATICK)
Natick, MA 01760-5017

Ronald J. Kuhbander
University of Dayton Research Institute
300 College Park Avenue
Dayton, OH 45469-0130

Thomas Bitzer
Hexcel Corporation
Dublin, CA 94568-0705

AUGUST 1992

Interim Technical Report Covering the Period October 1983 - November 1988

Approved for public release; distribution is unlimited

MATERIALS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6533

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility nor any obligation whatsoever. The fact that the government may have formulated, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise in any manner construed, as licensing the holder or any other person or corporation, or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FRANK FECHEK, Materials Engineer
Materials Behavior & Evaluation Grp
Materials Engineering Branch
Systems Support Division

THEODORE J. REINHART, Chief
Materials Engineering Branch
Systems Support Division
Materials Directorate

THOMAS D. COOPER
Chief
Systems Support Division
Materials Directorate

If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify WL/MLSE, Wright-Patterson AFB, OH 45433-6533 to help us maintain a current mailing list.

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1992

3. REPORT TYPE AND DATES COVERED
Interim; 10/83-11/88

4. TITLE AND SUBTITLE
LONG-TERM TROPIC ENVIRONMENTAL EXPOSURE OF ARMY STANDARD FAMILY (ASF) RIGID WALL HONEYCOMB SANDWICH PANELS

5. FUNDING NUMBERS
PE 69120
PR 2418
TA 04
WU 41

6. AUTHOR(S)
David A. Mikelson
Ronald J. Kuhbander
Thomas Bitzer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Natick Research, Development, and Engineering Center (NATICK), Natick, MA 01760-5017
University of Dayton Research Institute, 300 College Park Avenue, Dayton, OH 45469-0130
Hexcel Corp., Dublin, CA 94568-0705

8. PERFORMING ORGANIZATION REPORT NUMBER
UDR-TR-91-130
F33615-85-C-5094

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Materials Directorate (WL/MLSE)
Wright Laboratory
Wright-Patterson Air Force Base, OH 45433-6533
Frank Fechek (513)255-7484

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
WL-TR-91-4140

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Modular building concepts for lightweight, transportable tactical shelters incorporate such features as adhesively bonded sandwich wall construction of nonmetallic honeycomb core and aluminum skins. Tactical shelters are used in many locations throughout the world and consequently are subjected to a wide variety of environmental conditions. Experience has demonstrated that the hot-humid environment of the tropics is the most demanding on adhesively bonded shelter walls. The purpose of this investigation was to establish a physical and structural properties data base for tactical rigid wall honeycomb sandwich panels with long-term exposure to the tropical environment. Thirty-two sandwich panels were fabricated and subjected to the tropical environment at the U.S. Army Tropic Test Center in the Republic of Panama. Panels were of standard configuration, panels with hardware (latches, inserts, and repair patch), panels with no polysulfide sealant, and panels with simulated damage. Both Nomex and Kraft paper cores were included. Upon withdrawal from tropical exposure, each panel was weighed to assess moisture pickup, visually

(SEE ATTACHED PAGE)

14. SUBJECT TERMS
Tactical Shelters
Adhesive Bonded
Honeycomb Sandwich
Tropical Exposure
Testing

15. NUMBER OF PAGES
101

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

REPORT DOCUMENTATION PAGE (Concluded)

13. ABSTRACT (Concluded)

inspected for corrosion, local bulges, fungus growth, and sealant deterioration, and coin tap tested for delamination. Subsequently, each panel was machined into specimens and the effects of the tropical exposure determined. Test included: drum peel, flatwise tension, flatwise compression, sandwich flexure, insert pullout and torque, and sealant durometer.

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Concluded)

LIST OF TABLES

LIST OF TABLES (Concluded)

PREFACE

This report covers a 5-year study performed at the U.S. Army Tropic Test Center (USATTC) in the Republic of Panama to determine the effects of Long-Term Tropic Environmental Exposure on the physical and structural properties of ASF Rigid Wall Honeycomb Sandwich Panels. This study was performed under the direction of the U.S. Army Natick Research, Development, and Engineering Center, Natick, MA, and was administered by Mr. David A. Mikelson, Senior Mechanical Engineer. Mr. Mikelson was assisted by Mr. Ronald J. Kuhbander from the University of Dayton Research Institute (UDRI), Dayton, OH, and Dr. Thomas Bitzer from Hexcel Corporation, Dublin, CA. Mr. Kuhbander's efforts were funded by the Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio 45433-6533; Mr. Frank Fechek being the Project Engineer. Dr. Bitzer's support was funded by internal funds from Hexcel Corporation.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following:

1. USATTC Personnel
   George Downs and William Peart

For their assistance in the set up of exposure fixtures, withdrawal of panels from test sites, and initial set up of test apparatus.

2. UDRI
   Steve Caldwell and Don Byrge

For their on-site assistance in the 2-, 3-, and 5-year panel withdrawal, inspection, specimen cutting and testing.

3. Wright Laboratory, Material Directorate, WL/MLSE
   John Rhodehamel

For this assistance in the design of the test plan and panel design.

4. U.S. Army Armament Research & Development Center (ARDC)
   Ray Wegman

For administering the contract with Brunswick Corporation, Marion, Virginia, for the fabrication of the honeycomb sandwich panels.

5. NATICK
   Nick Patev

For preparing necessary drawings for the fabrication of the four types of panels.

6. NATICK

For bearing the cost of fabrication of the 24-Kraft paper honeycomb core panels as well as the USATTC overall test support cost.

7. E.I. DuPont de Nemours & Co. (Wilmington, Delaware)

For bearing the cost of fabrication of the 8-Nomex paper honeycomb core panels.

SECTION 1
INTRODUCTION

The Army Standard Family (ASF) of Tactical Rigid Wall International Organization for Standardization (ISO) shelters are general purpose in nature and are intended for providing a clean/dry live-in/and work-in environment for such applications as field hospital surgery, a pharmacy, a laboratory, a maintenance facility, a field bakery, a field modular print system, etc. They are deployed world wide and, consequently, are subjected to a wide range of environmental conditions. Experience has demonstrated that the hot, humid environment of the tropics is the most demanding on adhesively bonded shelter panels.

Natick's Tactical Shelters Organization in cooperation with the Wright Laboratory, Materials Directorate, Wright-Patterson Air Force Base, with support from the University of Dayton Research Institute (UDRI) and Hexcel, set out to establish for the first time a technical data base for shelter panel physical and structural properties with long-term exposure to the tropical environment. Thirty-two panels were fabricated and shipped to the U.S. Army Tropic Test Center (TTC) in the Republic of Panama for exposure and evaluation.

SECTION 2
PANEL DESCRIPTION

Twenty-four of the panels had 2-inch-thick resin impregnated Kraft paper honeycomb core, 3.8 lb/ft^3, 3/8-inch cell size per ASTM E1091. Open cell friable 3/4-inch-thick polyurethane foam insulation (1.5 lb/ft^3 density) was pressed within the honeycomb cells and were identified as panel numbers 1 to 24. Eight panels have 2-inch-thick, 4.0 lb/ft^3, 1/4-inch cell resin impregnated Nomex paper honeycomb core and the same 3/4-inch polyurethane foam insulation pressed into the cells and were identified as panel numbers 25 to 32. All of the panels were 4 feet wide and 8 feet long having the honeycomb core ribbon in the 8-foot length direction. The outside or top skin was 0.050-inch-thick 5052-H34 aluminum painted forest green and the inside or bottom skin was 0.040-inch-thick 5052-H34 aluminum painted white. Panels were made in accordance with Natick drawing 5-4-2844 for ASF hinged roof panel assembly except without hinges and all four edges were closed. The materials and processes used to fabricate these panels were defined by American Society for Testing and Materials (ASTM) Standards E864, E865, E866, E874, E990, and E1091 and Type 1, Class B polysulfide sealant per MIL-S-8802.

2.1 PANEL CONSTRUCTION

ASF deployable roof panels were constructed to assess the long-term effects on individual panel structural integrity as a function of hardware attachments (latches), inserts, simulated damage, repair patching, cutouts, and the use of polysulfide sealant. In addition, humidity indicators were installed to assess moisture intrusion into each panel during tropical exposure. Four types of panels were constructed and are identified in Table 1.

Details of the location of latches, inserts, cutouts, and repair patch are shown in Figures 1 and 2. The location of three 2-inch-diameter holes in skin(s) to simulate damage are shown in Figure 3. The humidity indicators installed during construction are sealed from the outside environment and are only visible on the inside skin. The indicators are designed to change color (blue to pink) when relative humidity within the panel reaches 70%, 80% or 95%. Color change is reversible if relative humidity drops below the indicated level. Location of the humidity indicators is shown in Figure 4.

TABLE 1

LONG TERM TROPICAL EXPOSURE PANEL IDENTIFICATION

(1) Standard Panels, closed edges, foam insulation, and polysulfide sealant
Kraft Core - Nos. 1, 2, 3, 4, 5, 6, 7
Nomex Core - Nos. 25, 26

(2) Hardware Panels, closed edges, foam insulation, latches, inserts, cutouts, repair patch, and polysulfide sealant
Kraft Core - Nos. 8, 9, 10, 11, 12, 13, 14
Nomex Core - Nos. 27, 28

(3) Simulated Damage Panels, closed edges, foam insulation, and 2-inch-diameter holes in skin(s) only to simulate damage, and polysulfide sealant
Kraft Core - Nos. 15, 16, 17, 18, 19, 20
Nomex Core - Nos. 29, 30

(4) No Sealant Panels, closed edges, foam insulation, and with no polysulfide
Kraft Core - Nos. 21, 22, 23, 24
Nomex Core - Nos. 31, 32

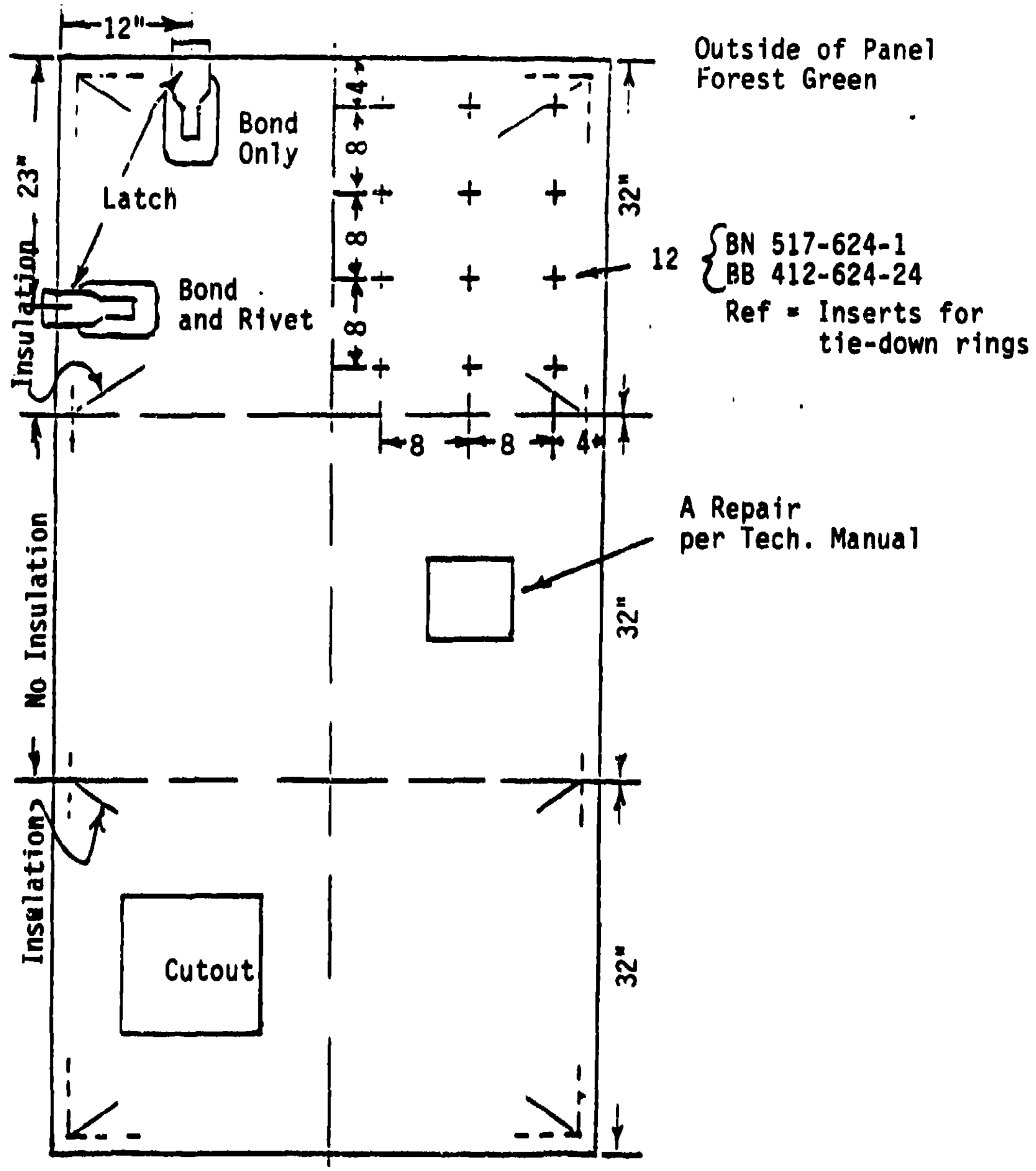


Figure 1. Outside of Hardware Panel Showing Location of Latches, Inserts, Repair Patch, and Cutout.

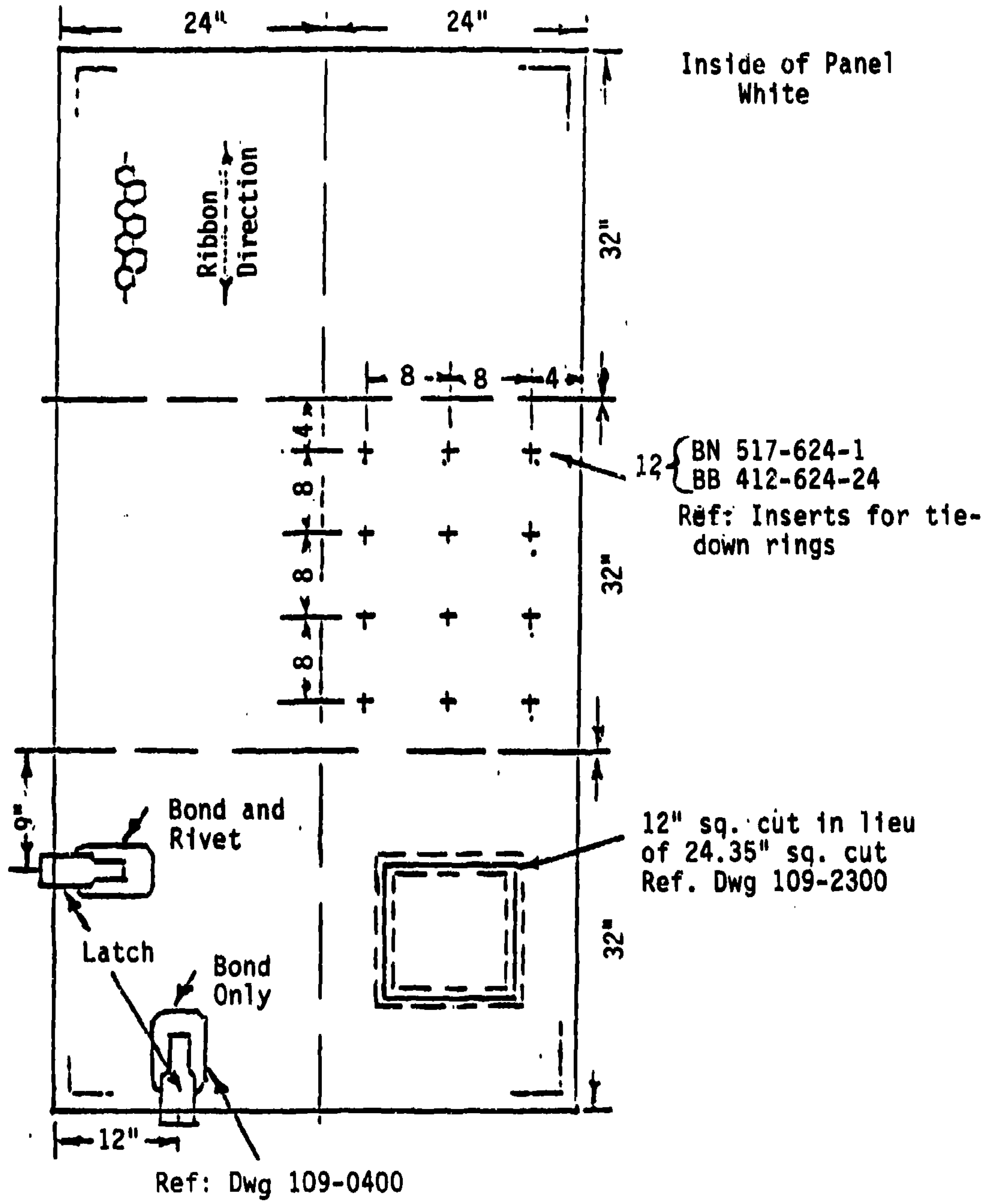


Figure 2. Inside of Hardware Panel Showing Location of Latches, Inserts, and Cutout.

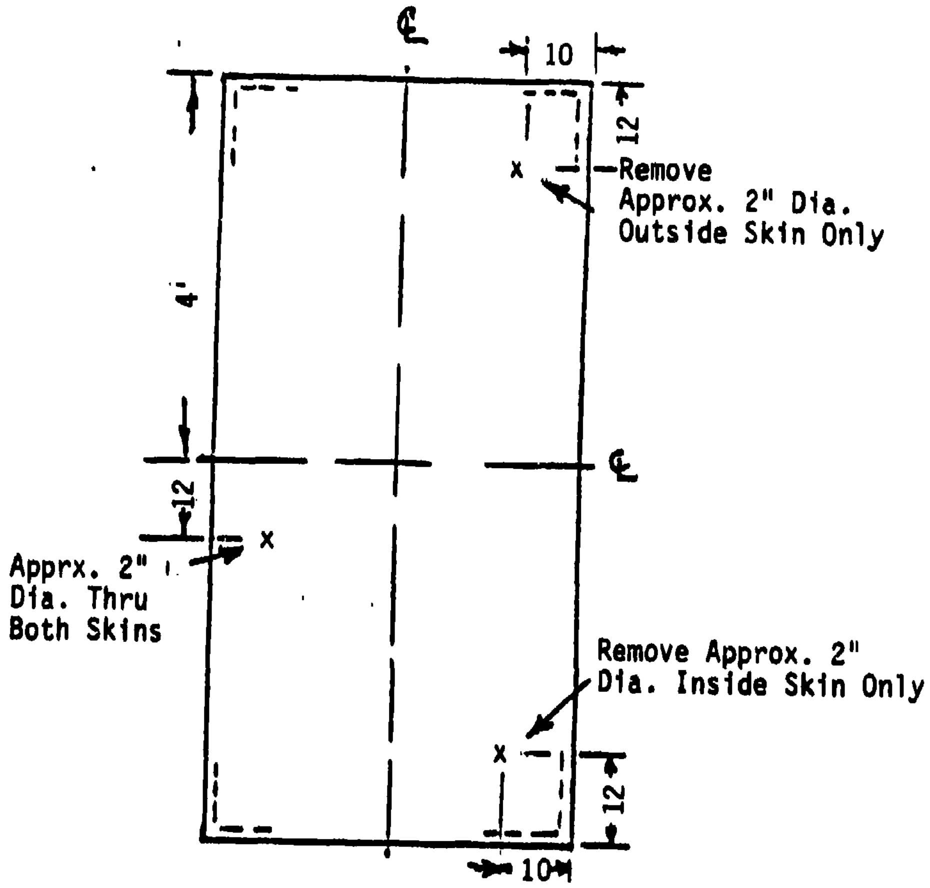
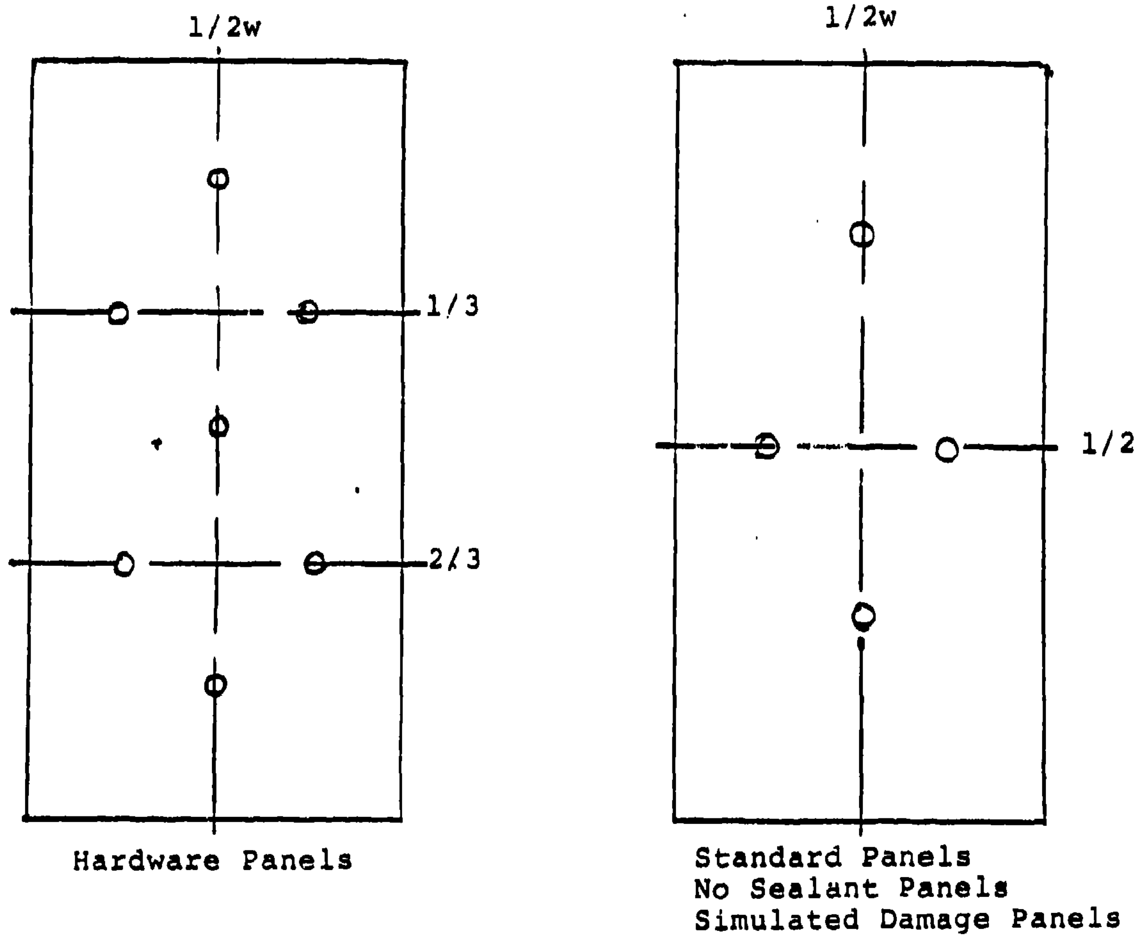


Figure 3. Location of 2-inch-Diameter Holes for Simulated Damage.

LOCATION OF GAUGES

INSIDE SURFACE



o HUMIDITY INDICATORS, NO. 2156
HUMIDIAL CORP., COLTON, CA

Figure 4. Location of Humidity Indicators.

The materials, equipment, and procedures used in the manufacture of the panels for environmental exposure were the same as that required in the production of tactical shelters. After manufacture the panels were packed in wooden crates and shipped to the USATTC in Panama.

SECTION 3
TEST PLAN

The plan was to deliver the 32 fabricated panels to the USATTC in Panama, in advance of the first visit by representatives of Natick, UDRI, and Hexcel. Upon arrival at TTC the representatives were to observe, instruct, and generally oversee the handling of the panels, and the preparation, cutting, and testing of the specimens. In reality this was not the case; actually, the work was performed by the representatives from Natick, UDRI, and Hexcel with assistance from USATTC personnel. This did not pose a problem because the representatives had many years of testing experience. Also, UDRI and Hexcel supplied the test fixtures required to perform the mechanical property tests on the USATTC Instron Universal test machine, Model No. 1125.

Prior to testing, each panel was to be visually inspected, coin tapped on both sides, and weighed. Also, all humidity indicators were to be inspected to ensure all were blue. Four panels would then be cut into test specimens for initial baseline data, 25 would be exposed to the tropical environment, and 3 would be stored at standard conditions (73°F, 50% R.H.) in the laboratory at TTC. Table 2 lists the panel numbers and withdrawal sequence.

Upon withdrawal, each panel was to be visually inspected for corrosion, bulges, fungus and algae growth, peeling of paint, sealant deterioration, etc. Each panel was to be weighed to assess moisture pick-up, and coin tapped over the entire surface of both sides to identify any areas of skin to core separation (i.e., delamination). Test specimen location and size were next drawn on each panel using a different precise line drawing for each of the four type panels. Next, each panel was cut into specimens using a deep throat band saw. Table 3 lists the type mechanical property measured, test specification and specimen size. Table 4 lists those same mechanical property tests, appropriate specification, and minimum requirement for use in tactical shelters. Figures 5 through 8 illustrate the panel diagram used in locating each specimen type in each panel configuration.

All panels were laid out on the white skin (bottom side during exposure) with the panel serial number in the upper right-hand corner. As shown in Figures 5 through 8 the standard, simulated damage, and no sealant panels were divided into 4 sections labeled A, B, C, and D. The panels with hardware were divided into 6 sections labeled A through F. The identification of these sections is shown in Figures 7 and 8. As shown in

TABLE 2
LONG TERM TROPICAL EXPOSURE PANEL WITHDRAWAL DATES

Exposure Time	Date	Panel Numbers
Control	Oct 1983	1, 8, 27, 29
6 Months	April 1984	2, 9, 15
1 Year	Oct 1984	3, 10, 16, 21, 31
2 Years	Oct 1985	4, 11, 17, 22, 25
3 Years	Oct 1986	5, 12, 18, 23
5 Years	Oct 1988	6, 7, 13, 14, 19, 20, 24, 26, 28, 30, 32

Panels 7, 14 and 20 were stored at standard conditions (73 ± 2.5°F and 50 ± 5% R.H.).

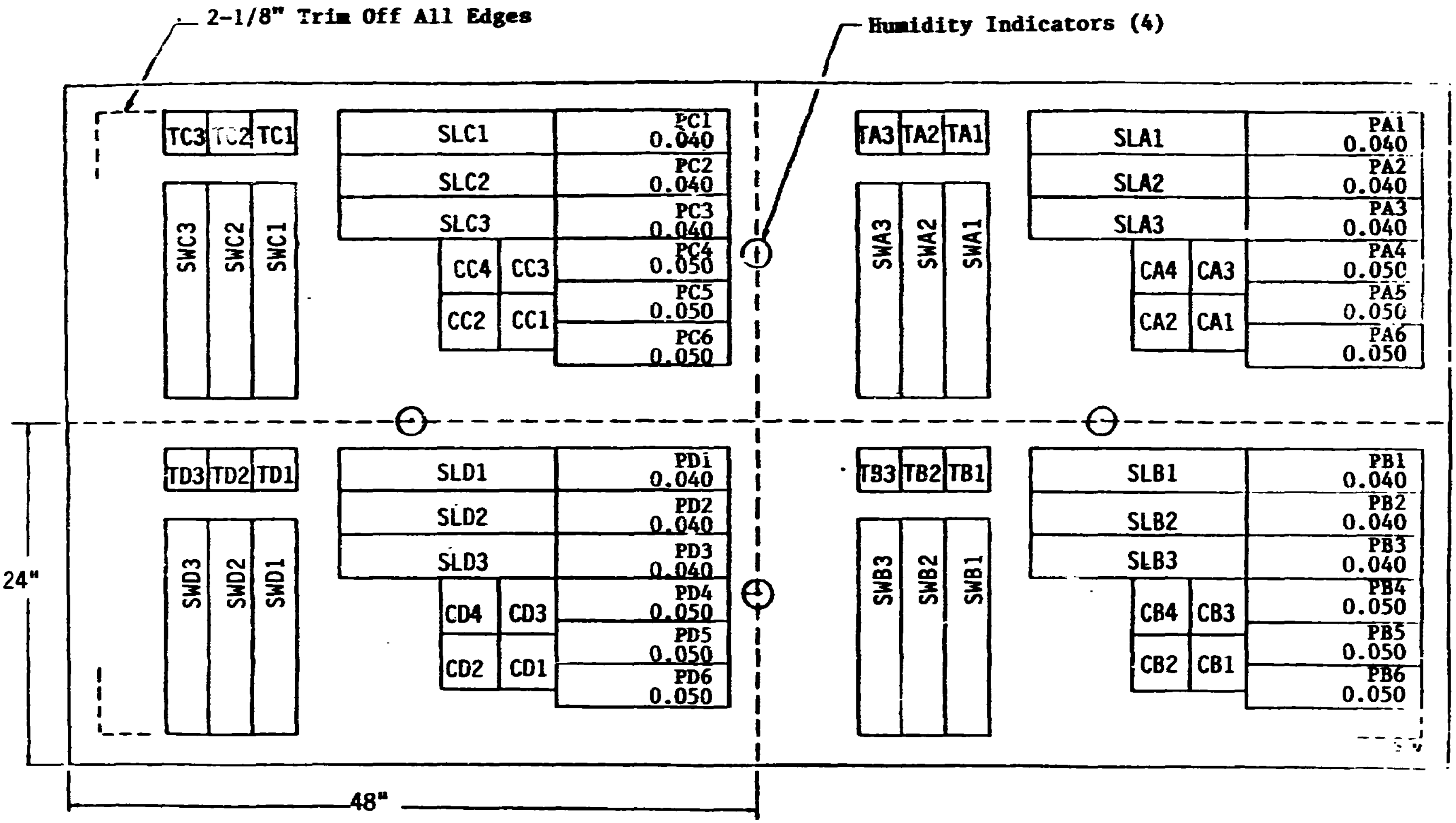
TABLE 3
MECHANICAL PROPERTY TESTS, SPECIFICATIONS, AND SPECIMEN SIZES

Type Test	Test Specification	Specimen Size
Climbing Drum Peel	ASTM D1781	3 inch x 12 inch
Flatwise Tension	MIL-STD-401B	3 inch x 3 inch
Flatwise Compression	MIL-STD-401B	4 inch x 4 inch
Sandwich Flexure	MIL-STD-401B	3 inch x 15 inch
Insert Pullout and Torque	MIL-S-44197A	N.A.
Sealant Durometer	ASTM D2240	N.A.

TABLE 4

MINIMUM REQUIREMENTS FOR MECHANICAL PROPERTIES FOR USE IN HONEYCOMB PANELS FOR TACTICAL SHELTERS

Type Test	Specification	Minimum Requirement
Climbing Drum Peel	ASTM E874	6.9 in-lb/in
Flatwise Tension	ASTM E1091	306 psi
Flatwise Compression	ASTM E1091	404 psi
Sandwich Flexure	ASTM E1091	180 psi, "L" direction
Sandwich Flexure	ASTM E1091	113 psi, "W" direction
Insert Pullout	MIL-S-44197A	1600 lb, 80% 2000 lb, proof
Insert Torque	MIL-S-44197A	384 in-lb, 80% 480 in-lb, proof
Sealant Durometer	MIL-S-8802F, Amend. 1	35 Type A for Type 1, Class B Sealant

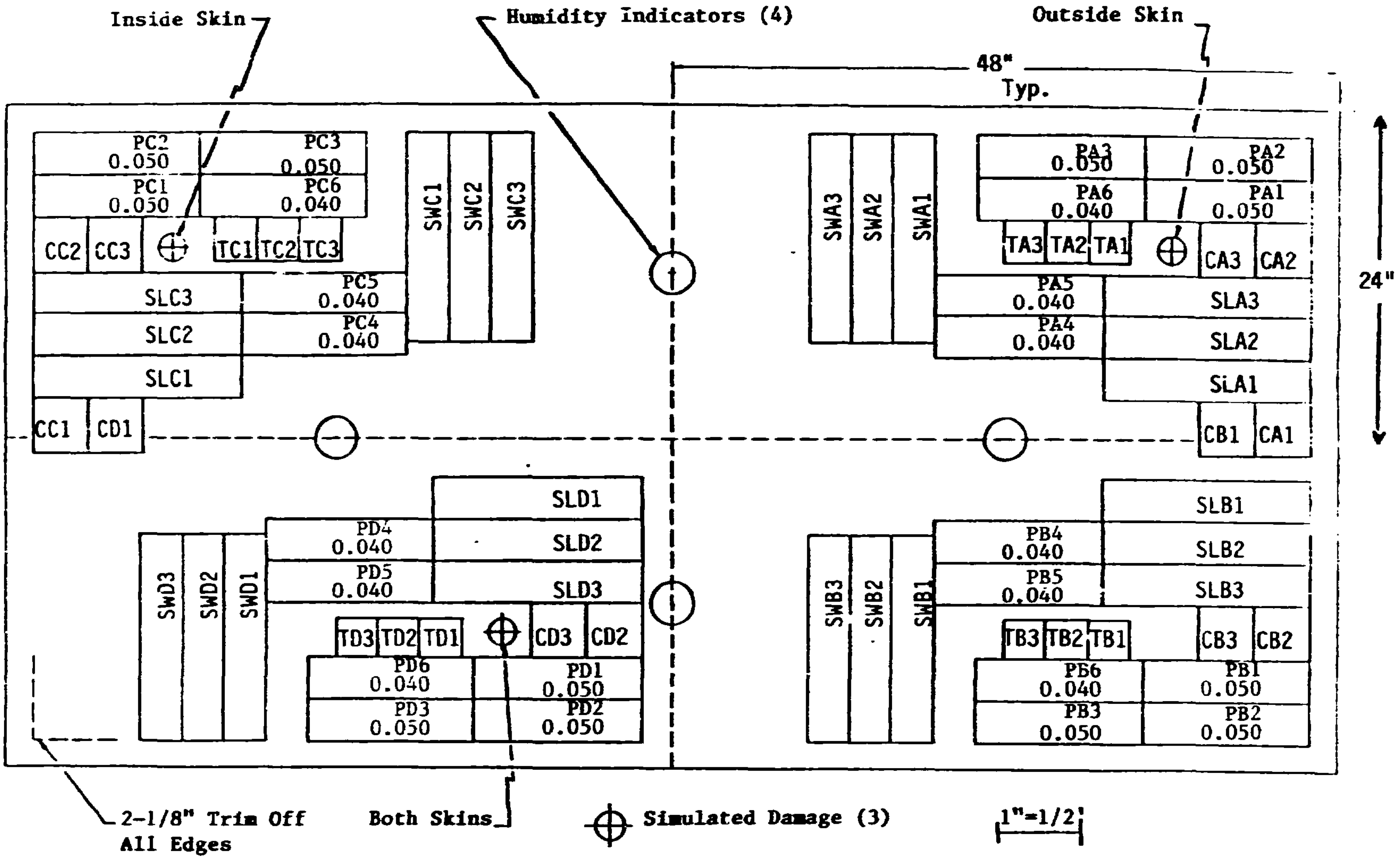


Standard Configuration Panels - Kraft Core Nos. 1 to 7 Nomex Core Nos. 25, 26

No Polysulfide Sealant - Kraft Core Nos. 21 to 24 Nomex Core Nos. 31, 32

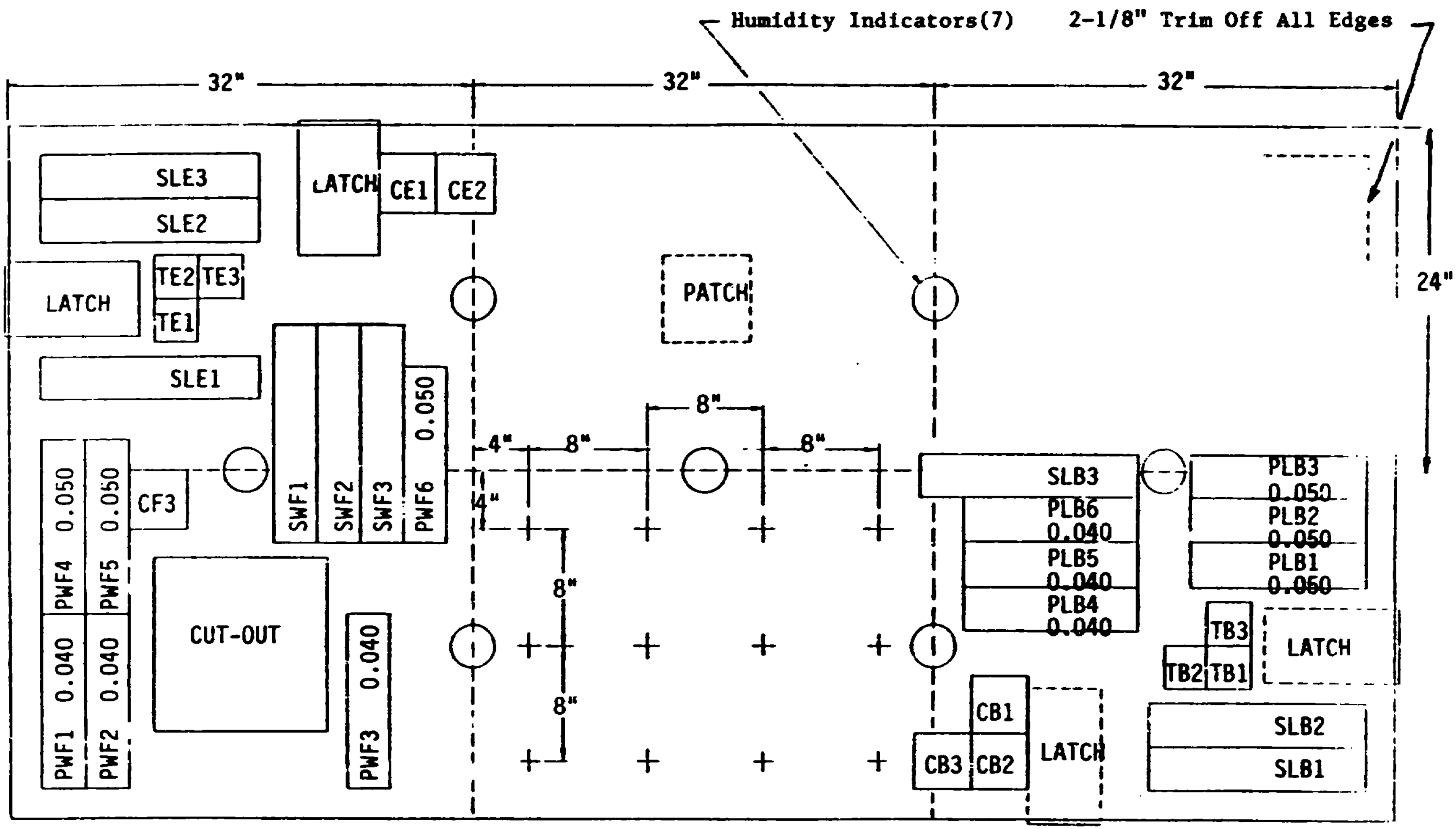
1"=1/2

Figure 5. Specimen Location from Standard Configuration and No Polysulfide Sealant Panels.



Simulated Damage Panels - Kraft Core Nos. 15 to 20   Nomex Core Nos. 29, 30

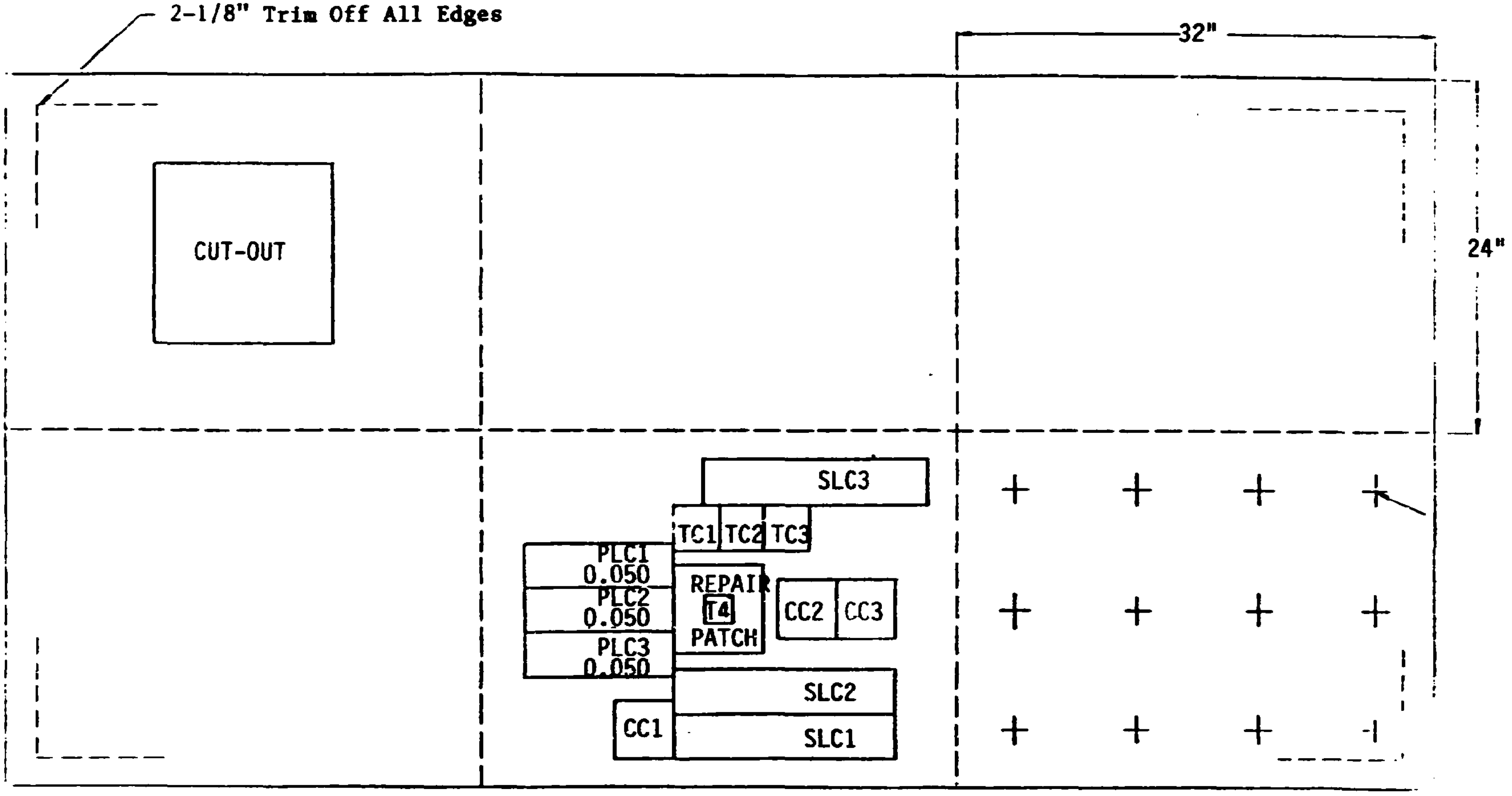
Figure 6. Specimen Location from Simulated Damage Panels.



Inside View - White Side

Panels With Hardware & Inserts - Kraft Core Nos. 8 to 14   Nomex Core Nos. 27, 28

Figure 7. Specimen Location from Inside (White) of Hardware Panels.



• T4 is a 2" x 2" Tension Specimen on Center of Repair Patch

1"=1/2"

Outside View - Green Side

Panels With Hardware & Inserts - Kraft Core Nos. 8 to 14   Nomex Core Nos. 27, 28

P-Peels = 3"x12"   C-Compression = 4"x4"   T-Tension = 3"x3"   S-Shear = 3"x15"

Figure 8. Specimen Location from Outside (Green) of Hardware Panels.

Figures 5 through 8, each specimen is identified for panel number, test type, ribbon direction (required on peel specimens from hardware panels only), section in panel, and specimen number. The peel specimens were also identified indicating the test skin, 0.050-inch-thick green skin or 0.040-inch-thick white skin. The code used for specimen identification is shown in Table 5.

TABLE 5

CODE USED FOR INDIVIDUAL SPECIMEN IDENTIFICATION

Panel No.	Type Test	Ribbon Direction(1)	Location in Panel	Specimen Number
8	P	L	C	4

NOTE: (1) Not required for tension and compression specimens. Required for peel specimens for hardware panel only.

Test and Direction	Location in Panel
P = Climbing Drum Peel	A
C = Compression	B
T = Tension	C
S = Shear	D
L = Ribbon Direction	E
W = Transverse Direction	F

0.040 on peel specimen indicates that inside skin (white) should be test side.

0.050 on peel specimen indicates that outside (green) should be test side.

SECTION 4
CONTROL PANEL WITHDRAWAL

In early October 1983, representatives from Natick, UDRI, and Hexcel arrived in Panama City, Panama. Unfortunately, between General Omar Torrijos H. International Airport and the hotel the representative from UDRI had his briefcase stolen from the rent-a-car while seeking directions at a gas station. The significance of this is the drawings indicating the specimen locations for each panel were in the briefcase. This was the only copy available in Panama. Once settled into the hotel, communications were established with UDRI in hopes of having an additional copy sent to Panama. More will be discussed on this later.

4.1 UNCRATING AND PANEL INSPECTION

The panels had been delivered to the TTC prior to the arrival of the working party. The crates were stored in a warehouse at TTC. Upon opening the crates of panels fabricated with Kraft paper core, it was observed that each panel was separated from the other with wood slats wrapped with soft packing paper, as shown in Figure 9. The Nomex panels were not properly packed with wood slats separating each, see Figure 10, and small "dings" caused by the banging of panel humidity indicators on adjacent panels were observed and are shown in Figure 11. These "dings" were marked and were observed during the tropical exposure to assure no debond growth. Each panel was then carefully inspected for paint and sealant peeling, dents, scratches, or any other damage which may have occurred during shipment. Other than the "dings" on some of the Nomex panels, all the panels were in excellent condition. Each panel was then identified according to the numbering system previously shown in Table 1. The panel number was always placed on the white-inside skin in the same corner as was the manufacturer's serial number.

4.2 WEIGHING AND COIN TAP TESTING

Upon completion of visual inspection and identification, each panel was weighed and coin tap tested. Figure 12 illustrates a panel being weighed. Individual panel weights ranged from a minimum of 95 pounds for a standard panel to a maximum of 115 pounds for a hardware panel. The exact weight of each is shown in Tables 12 and 13 of Section 10 - "Discussion of Results." After weighing, each panel was coin tap tested as shown in Figure 13. Coin tap testing was performed using a 25-cent piece and always

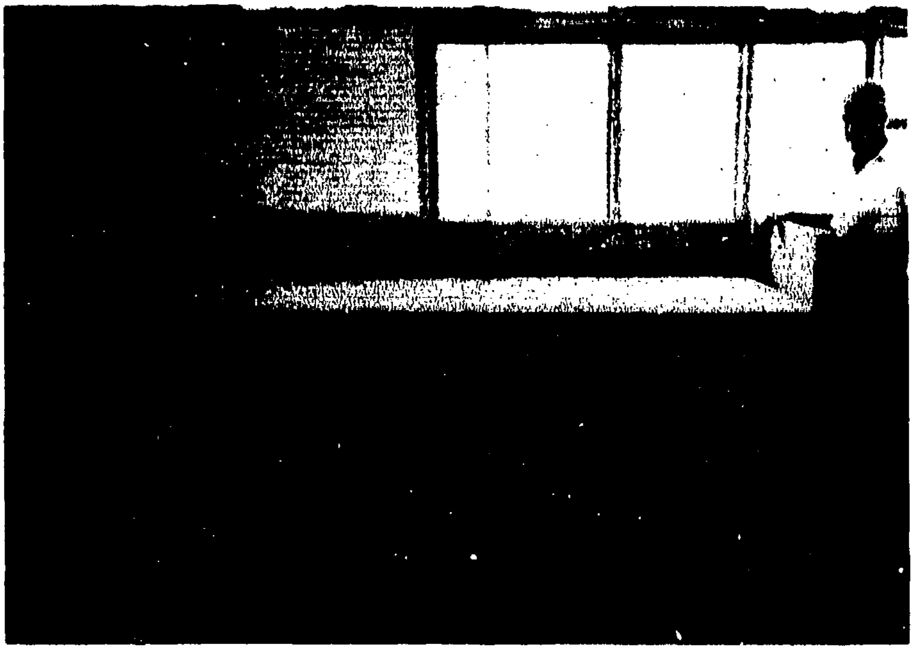


Figure 9. Properly Packed Panels With Wood Slats.

Figure 10. Improperly Packed Panels Without Wood Slats.

Figure 11. Small "Dings" in Nomex Panels Caused by Humidity Indicators During Transit.

Figure 12. Weighing of a Hardware Panel.

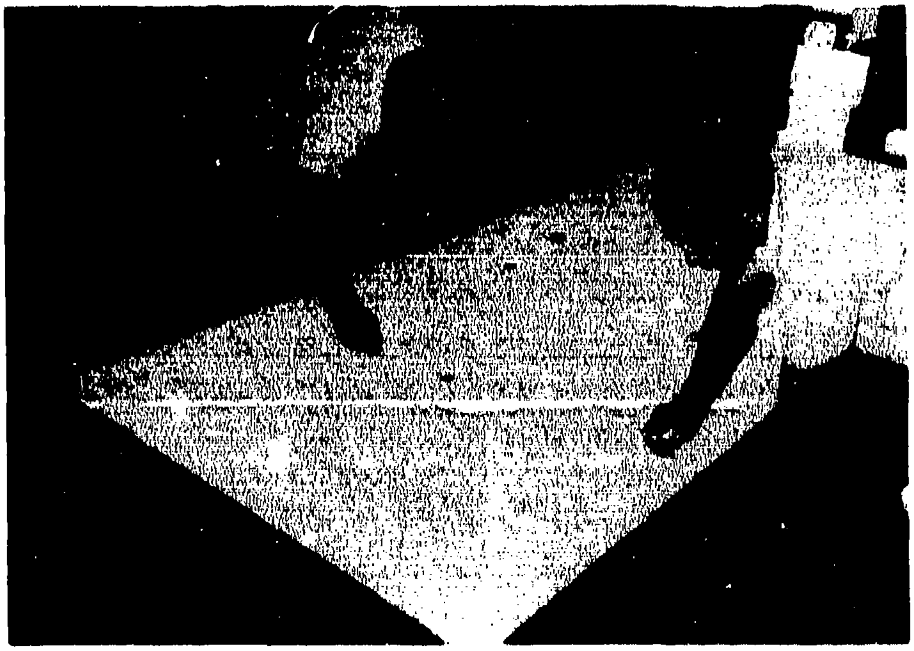


Figure 13. Coin Tap Testing of Simulated Damage Panel.

by the same two individuals. Coin tap testing, when done properly by trained personnel, can reveal debonds or delaminations. The panels were thoroughly tap tested over the entire surface of both sides. The only possible debonds noted where in the center of the "dings" on the Nomex core panels. On each following withdrawal these panels were closely examined to assess if any skin to core separation around the dings was noticeable. Also shown in Figure 13 is a simulated damage hole in skin, humidity indicators, and panel identification. Although not clearly shown, each panel was carefully laid on the wood slats so not to damage the paint or panel in anyway.

4.3 PREPARING PANELS FOR LONG-TERM TROPICAL EXPOSURE

Three panels, numbers 7, 14 and 20, were placed in storage in the TTC Laboratory which is maintained at 73 ± 2.5°F and 50 ± 5% R.H. These panels were withdrawn at the end of the 5-year study to obtain comparative results with those panels subjected to long-term tropical exposure. Twenty-five panels were individually loaded onto a 2½-ton truck and transported to the exposure site, called Chiva-Chiva. Wood slats were placed between each panel so as not to cause any damage during the approximate 10-mile trip. Prior to the October 1983 visit, TTC personnel constructed aluminum angle racks for holding the panels during exposure. The panels were positioned at a 30 degree angle to the horizontal and facing east to assure proper water drainage and maximum sun (solar) exposure. Each panel was tightly fitted within each aluminum framework, but was not bolted in place or otherwise restrained in anyway. Also, each panel was positioned such that its forest green colored outside skin faced up toward the sun, and the 8-foot panel length was vertically oriented with the panel identification at the highest edge.

The assembled aluminum angled racks at Chiva-Chiva are shown in Figure 14. The tropical environment aging site was in a clearing at Chiva-Chiva which was fenced and under guard 24 hours a day. Figures 15 and 16 show the transport truck being unloaded and a panel being placed on the rack. Several panels did not fit well in the racks, but the TTC personnel made the necessary adjustments. Figure 17 shows several of the panels in the racks as the exposure began. While placing the panels in the racks, it was observed that the forest green side was becoming very hot from the sun rays. While sighting down the edge of a panel, one could see that the panel was bowing upward in the center about 1/2 inch. Upon cooling from rain or night fall, the panels would relax and once again would be flat. Later, skin temperature measurements were taken during sunny and cloudy conditions, and the bow in panel was measured and reported.

Figure 14. Panel Holding Aluminum Racks at Chiva-Chiva Test Site.

Figure 15. Unloading Panels from 2 1/2-ton Truck.

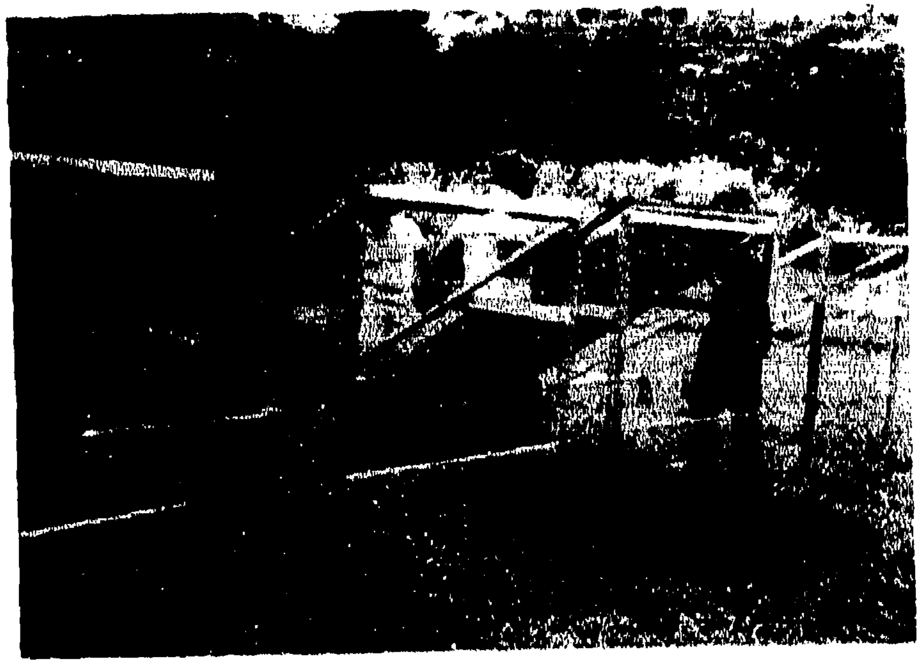


Figure 16. Placement of Panels in Holding Racks.

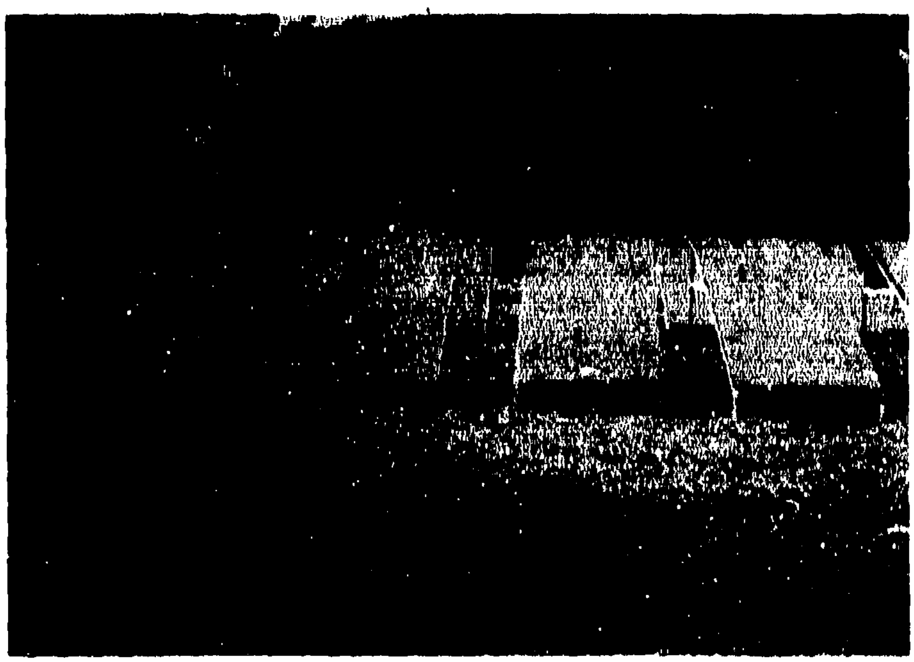


Figure 17. Panels in Holding Racks Beginning the 5-Year Tropical Exposure.

Once the panels were in the holding racks, the 5-year tropical exposure began. Periodically, Army personnel from the TTC would visit the Chiva-Chiva test site and examine the panels and the humidity indicators.

4.4 PANEL LAYOUT AND SPECIMEN MACHINING

Four panels were then prepared for the layout and band saw cutting of test specimens for control (i.e., base-line) data. These panels, as indicated in Table 2, were Nos. 1, 8, 27, and 29. Panel No. 1 was a standard configuration with Kraft paper core, No. 8 was a hardware panel with Kraft paper core, No. 27 a hardware panel with Nomex core, and No. 29 a simulated damage panel with Nomex core.

There was some difficulty locating a band saw with a deep throat which was necessary for cutting the 4-ft x 8-ft panels. Finally one with a throat of 3 feet was located at the Facility Engineering Department. The four panels were then transported to that facility. However, the copy of the drawings giving the specimen locations on each panel had not yet arrived despite promises from the airlines. Therefore, new drawings were made relying on memory and judgement. Figures 5 to 8 are the results of the new drawings made in that facility.

Each panel was laid out according to the appropriate drawing as shown in Figure 18. Each specimen was carefully identified for panel number, test type, location within the panel, specimen number, and where appropriate the core ribbon direction. Also, some climbing drum peel tests were later run with the 0.040-inch-thick inside skin and some were run with the 0.050-inch-thick outside skin. These were identified on the panel drawings.

The four control panels were then carefully cut into more than 300 individual test specimens, as shown in Figure 19. Although this task was time consuming and tiring, little difficulty was encountered. A good sharp metal cutting blade was used and would cut through the sandwich panel with ease and would leave only minor burrs. Cutting through the edge closeouts would dull the blade rapidly, so this type of cut was held to a minimum. Personnel from the Facility Engineering Department assisted in cutting and were very cooperative. As soon as the specimens were machined, they were placed in large plastic bags to maintain the moisture level that may be within the specimen.

Figure 18. Panel Marking for Specimen Machining.

Figure 19. Cutting Test Specimen on Band Saw.

The climbing drum peel test specimens required a notch be cut at each end so that the specimen would fit in the loading fixture. Some of these were cut by hand with a hack saw, but it was found to be quicker and easier to use the band saw and all further specimens were done this way.

4.5 MECHANICAL PROPERTY TESTING

After machining, the plastic bags containing the test specimens were delivered to the Materials Laboratory at the Tropic Test Center. Here the specimens were prepared for test. First each specimen was deburred and then the appropriate physical dimensions were taken and recorded in a laboratory notebook. The specimens were then returned to the plastic bags until the tests were performed.

The hardware panel had inserts (hi-shear 3/8-inch diameter and 24 threads per inch [3/8-24-UNF]) in the top (outside) and bottom (inside) skins. Insert pullout (2000 lbs) and torque (480 in-lbs) were performed in accordance with Paragraph 3.5.3 of MIL-S-44197A. Figure 20 shows a pullout test in progress. Each insert passed this test.

Durometer testing on polysulfide sealant was performed and found to be 60 to 70 on Shore Type A durometer. This is an acceptable hardness value.

In order to perform flatwise tension, loading blocks were bonded to both faces. A limited number of loading blocks were shipped to TTC and had arrived the day the specimens were delivered to the Materials Lab. Bonding began at once because tests would have to be performed, blocks cleaned, specimens rebonded and testing repeated. Figure 21 illustrates the bonding operation in progress. The flatwise tension specimens were lightly sanded and solvent wiped before bonding; however, about 30% of the specimens debonded during the test. The adhesive used was room temperature curing and it was given 16 hours (overnight) minimum before testing. The rebonding operation and an insufficient number of loading blocks made flatwise tension testing a problem. A flatwise tension test in progress can be seen in Figure 22.

It was uncertain if all the tests could be completed during the alloted time for this visit to the TTC. It was decided to run at least some of each type of test to instruct TTC personnel so that they could complete the control testing on their own if need be. Previous to the visit, UDRI had sent to the TTC some specimens of each type for use in instructing the personnel in Panama. The climbing drum peel test was set up and tests were conducted with the samples from UDRI as shown in Figure 23. In setting up the

Figure 20. Insert Pullout Test.

Figure 21. Bonding Flatwise Tension Loading Blocks.

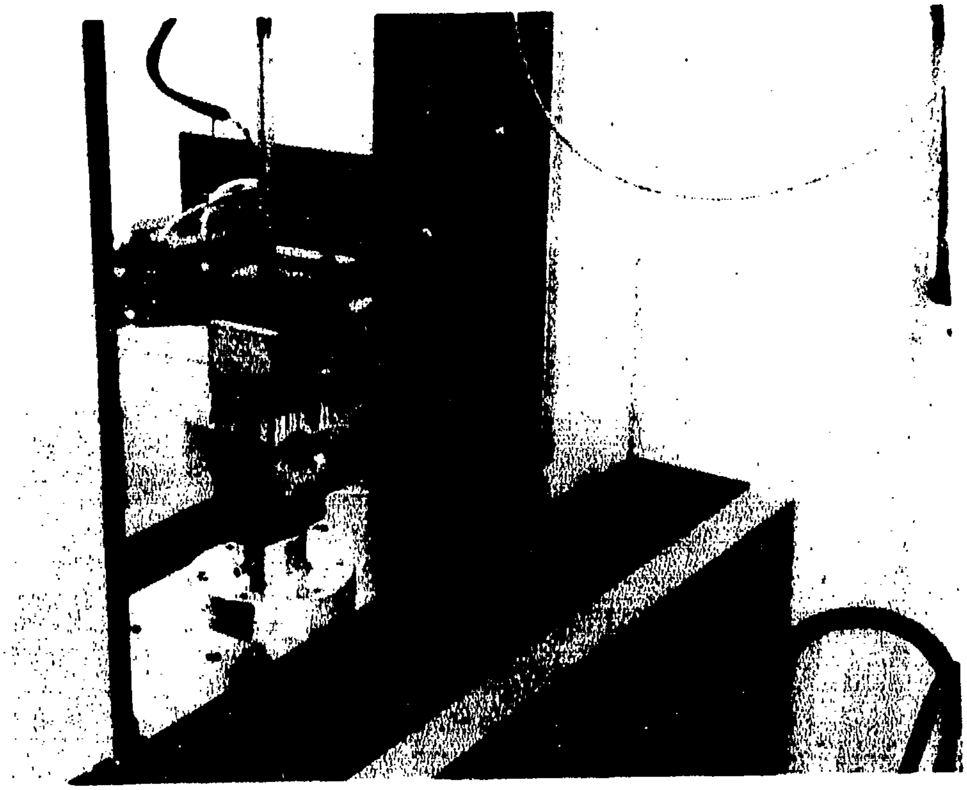


Figure 22. Flatwise Tension Test in Progress.

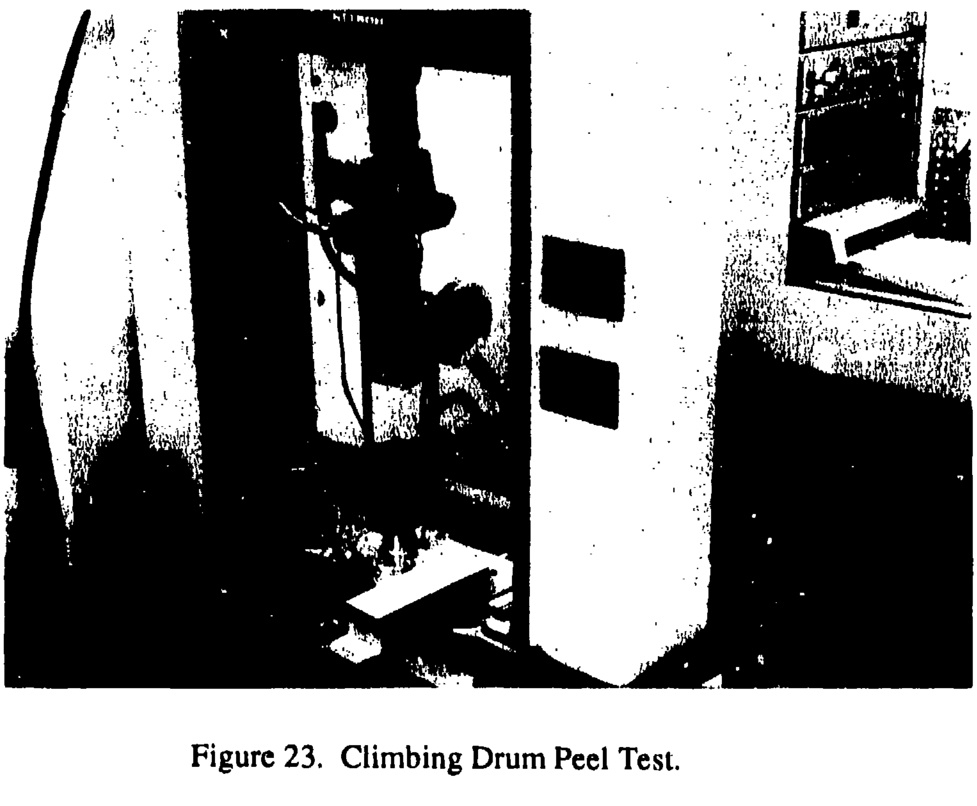


Figure 23. Climbing Drum Peel Test.

peel test, it is necessary to calibrate the fixture with a piece of the facing material so that the force required to bend that material around the drum can be subtracted from the total measured force. This must be done for both the 0.040-inch-inside and 0.050-inch-outside thick skins. Unfortunately the aluminum required for calibration was not sent to the TTC, and none was available. However, the TTC personnel were instructed on the test procedures using the samples from UDRI and if necessary the calibration could be completed later.

The test machine was then set up for the beam shear tests, as shown in Figure 24. The TTC personnel were instructed with samples sent by UDRI and then a few tests were completed with samples from each panel. To be consistent all beam shear tests would be performed with the 0.050-inch-thick skin up. No problems were encountered during the instruction or testing, but it was decided to change the test setup to compression to assure that at least some tests of each type would be performed during this visit. This decision turned out to be critical.

The test machine was set up for compression testing as shown in Figure 25. Several tests were performed with specimens sent to TTC by UDRI. One test was then successfully performed from Panel No. 1. While testing the second specimen, the test machine malfunctioned and the crosshead loaded the specimen at a rapid, uncontrolled speed and continued until the specimen was crushed and the gears were jammed. Several hours were spent trying to determine the cause and to assess the damage. It became obvious that the damage was significant and repair would require assistance from Instron. Also, it was obvious that the tests would not be completed during this visit.

Having some control data was critical to the success of this program. Therefore, it was decided to take a representative number of each type of specimen from each panel back to Hexcel and UDRI. The remainder of the control specimens could be tested by TTC personnel upon repair of the test machine. Specimens were then sealed in plastic bags, boxed, and hand-carried back for test. Flatwise tension specimens were taken to UDRI. Climbing drum peel, compression, and beam shear were taken to Hexcel. Those specimens were tested at those organizations immediately upon return. This assured that the program would have at least some control data, and this turned out to be a good decision. Inadvertently, the remaining machined control test specimens were left in the laboratory unprotected without being packaged in plastic bags. Thus, as it turned out, for six months each of these machined control test specimens had its honeycomb core and its bond line between it and the skins exposed on four sides to the lab environment. The

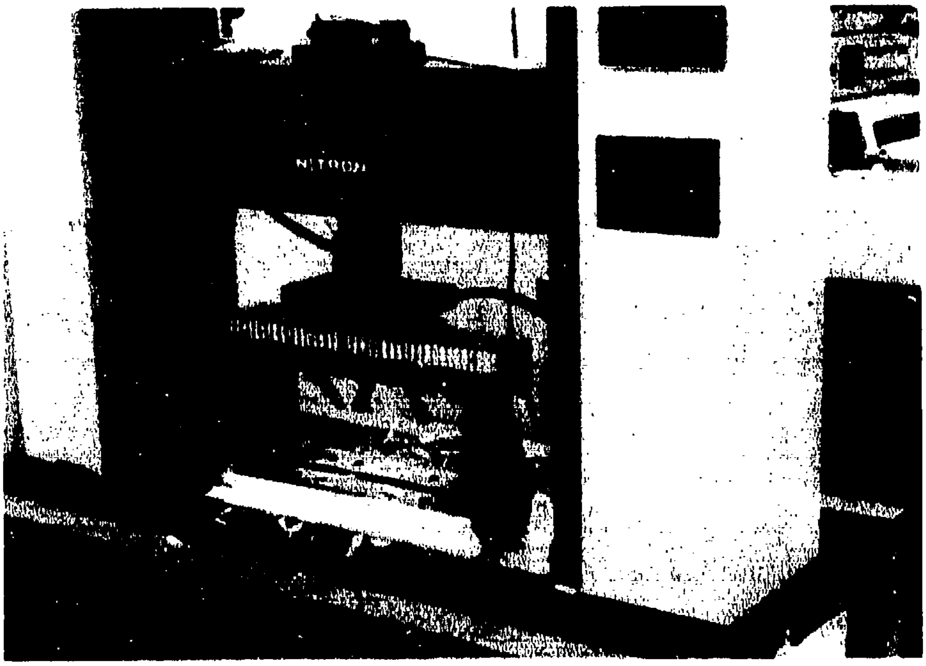


Figure 24. Beam Shear Test Setup.

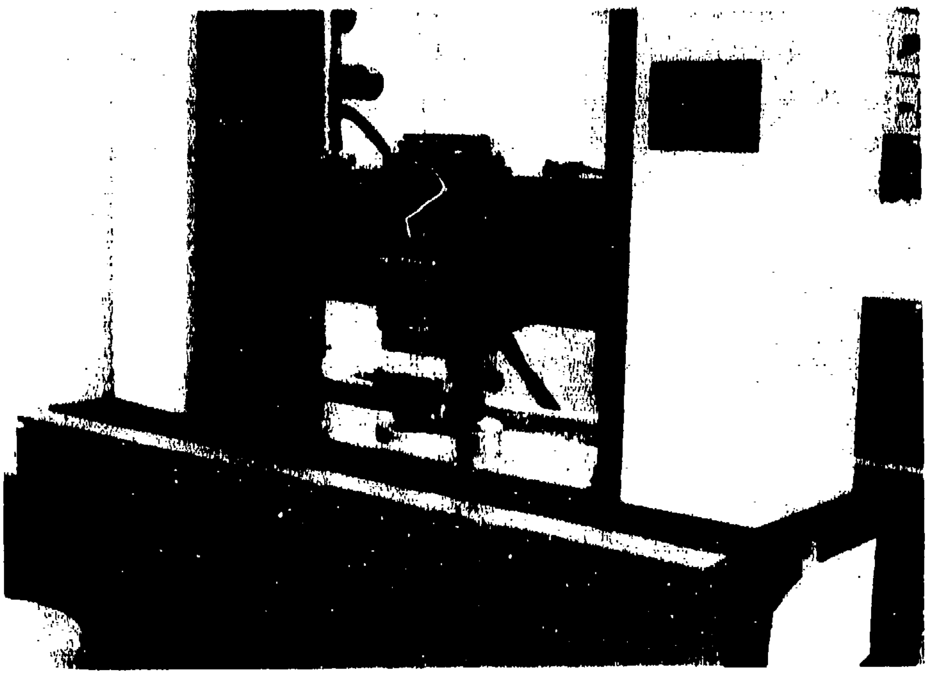


Figure 25. Flatwise Compression Test Setup.

effects on these specimen structural properties of this unplanned lab exposure shall be discussed in Section 5.

The control (i.e., base-line) data obtained from the few test specimens tested during this initial visit to TTC combined with those tested at UDRI and Hexcel indicated panel structural properties that exceeded all the minimum values specified in ASTM E1091 and E874 with one exception, the average climbing drum peel strength for the 0.050-inch-thick outer aluminum skin to Kraft paper core was 4.1 in-lb/in for Panel No. 8. The other 8 average individual panel skin to core climbing drum peel tests (including that of Panel No. 8's opposite 0.040-inch-thick aluminum skin to core) exceeded the minimum 6.9 in-lb/in value called out in ASTM E874. The climbing drum peel test was developed to evaluate both metal-to-metal adhesive bonds and sandwich panel construction. However, it was not intended to evaluate either with skin thicknesses of 0.040 and 0.050 inch, but rather 0.020 inch. The thicker skins used in roof panels for shelter construction do not easily bend around the drum. However, it is believed that the peel data obtained within this program can be compared over the 5 years of exposure. More elaboration of this will be given in the discussion of the results later in this report.

The repair of the Instron took much longer than anticipated. Transportation of parts and/or servicemen to the TTC in Panama is not as quickly accomplished as would service in USA. The next scheduled visit to Panama was to be in 6 months. It took nearly that long to repair the test machine and complete calibration. Some of the remaining lab exposed machined control specimens were tested 1 week prior to the 6-month withdrawal date and some during that visit. Further discussion on these tests can be found in Sections 5 and 10.

SECTION 5
SIX-MONTH WITHDRAWAL

In early April 1984, the same representatives from NATICK, UDRI, and Hexcel arrived in Panama City, Panama. The arrival was fortunately uneventful. Prior to the trip to Panama many of the supplies had been sent to the TTC. These supplies included adhesive for flatwise tension, 5052 H34 aluminum sheet stock of 0.040 and 0.050 inch thick for calibrating the climbing drum peel fixture, extra copies of panel diagrams, and some test fixtures. The supplies had arrived and were in the TTC Materials Lab.

As mentioned in the previous section, the majority of the control specimens were left accidentally unpackaged (i.e., exposed to the lab environment) at TTC for test once the Instron had been repaired. The remaining beam shear and compression specimens had been tested the last week in March 1984, and the remaining climbing drum peel and flatwise tension specimens had yet to be tested. These specimens would be tested at the same time as those for the 6-month withdrawal. Unfortunately, all of the specimens left at TTC that sat for the 6-month period were not in plastic bags and were, in fact, exposed to the laboratory environment, 73°F and 50% relative humidity. In retrospect, the specimens should have remained sealed in plastic bags. Fortunately, in Oct/Nov 1983, some specimens from each control panel for each type of test were evaluated at TTC, UDRI, or Hexcel. This did require some alterations to the test plan. The revised withdrawal schedule is shown in Table 6.

TABLE 6
REVISED LONG-TERM TROPICAL EXPOSURE WITHDRAWAL DATES

Exposure	Date	Panel Nos.
Control	Oct 1983	1, 8, 27, 19
Machined specimens exposed in lab for 6 months*	Apr 1984	1, 8, 27, 29
6 Months	Apr 1984	2, 9, 15
1 Year	Oct 1984	3, 10, 16, 21, 31
2 Years	Oct 1985	4, 11, 17, 22, 25
3 Years	Oct 1986	5, 12, 18, 23
5 Years	Oct 1988	6, 7, 13, 14, 19, 20, 24, 26, 30, 32

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

5.1 PANEL WITHDRAWAL FROM CHIVA-CHIVA EXPOSURE SITE

All of the panels at the Chiva-Chiva exposure site were inspected. The forest green paint on the top skins was beginning to fade but was not chipped or peeled except on some latches on hardware panels. Figure 26 illustrates a latch with some paint peeling. None of the latches on the white bottom side of the panels had paint peeling. Note that all of the latches are zinc plated steel. All of the panels were tap tested on both sides. No evidence of debonding was found. Careful attention was given around the areas of the previously mentioned "dings." No evidence of debonding, corrosion or further paint peeling was noted. Also, all of the humidity indicators were blue indicating no water or moisture intrusion into the panels. Some fungus was beginning to grow on the white side of the panels. All in all, the panels looked in excellent condition. Three of the panels were then removed from the racks and transported back to the TTC Materials Lab. The three panel types are shown in Table 7. Upon returning to the lab, the panels were weighed and no change was measured from the original, indicating no water pickup (see Table 7).

TABLE 7

SIX-MONTH WITHDRAWAL PANEL IDENTIFICATION AND WEIGHTS

Panel No.	Type Core	Configuration	Weights, lb		Pick Up (lb)
			Initial	6 Months	
2	Kraft	Standard	95.15	95.09	-0.06
9	Kraft	Hardware	114.63	114.81	0.18
15	Kraft	Simulated Damage	94.75	94.81	0.06

5.2 PANEL LAYOUT AND SPECIMEN MACHINING

After weighing at the Materials Lab, the panels were transported a short distance to the Facility Engineering Department. Arrangements were made with the machine shop in advance. The bandsaw was reserved and one of the same individuals who helped cut control panels was requested and that request was granted. Before laying out the panels, they were washed with warm water and dried with paper towels. All of the fungus and dirt was easily removed.

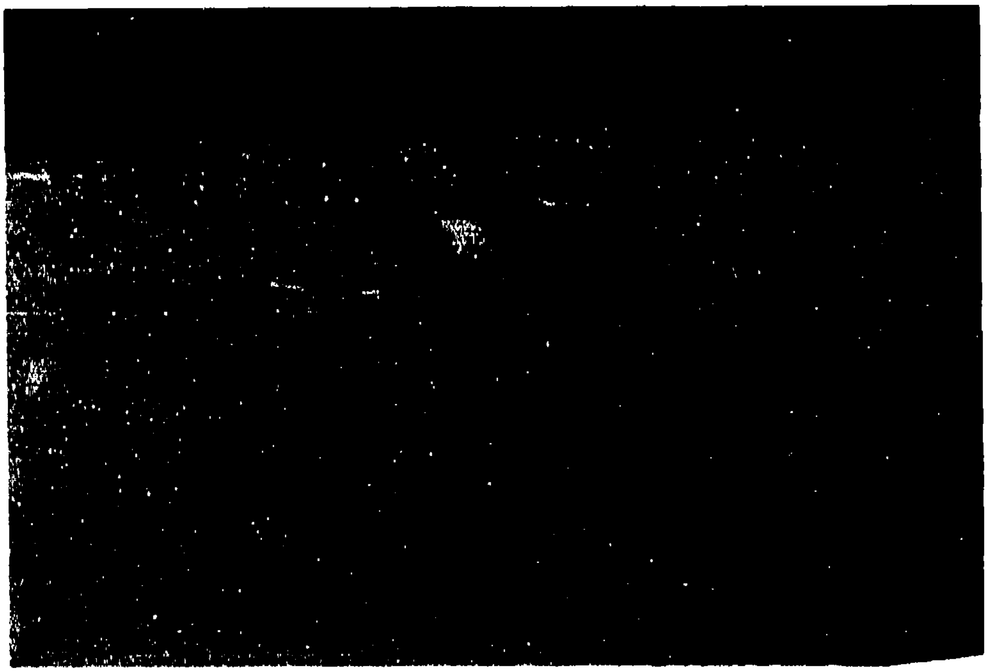


Figure 26. Paint Peeling on Latch After 6-month Tropical Exposure.

The panels were laid out according to the drawings prepared on the previous visit. Once again each specimen was carefully identified for panel number, test type, location within the panel, specimen number, and where appropriate core orientation (i.e., L or W). The machined specimens were placed in sealed plastic bags as soon as possible. No difficulties were encountered during layout and specimen machining.

5.3 MECHANICAL PROPERTY TESTING

The plastic bags containing the test specimens were delivered to the Materials Laboratory at the Tropic Test Center. Here the specimens were prepared for test. Each specimen was deburred and then the appropriate physical dimensions were taken and recorded in the laboratory notebook. The specimens were then returned to the plastic bags until the tests were performed.

During the initial visit to Panama, the flatwise tension tests proved to be one of the most time consuming. The specimens had to be sanded and solvent wiped then bonded to the loading blocks. It was found that it is imperative that the paint be removed from each specimen surface prior to adhesive application to assure that the loading blocks do not pull off during the test. Figures 27 and 28 show the equipment and technique used to remove the paint. Care was taken not to heat the specimen and thereby remove any absorbed moisture within the honeycomb and/or adhesive. The remaining flatwise tension specimens, which had originally been intended for control and are now considered machined specimens exposed to lab for 6 months, were tested along with the 6-month tropical.

Before testing the climbing drum peel specimens, the fixture was calibrated using 0.050- and 0.040-inch-thick 5052-H34 aluminum which had been sent to the TTC in advance to this visit. The loads required to raise the fixture and bend the aluminum were stamped on the side of the fixture as a permanent record. The load required to raise the fixture with no metal was 20.3 lbs, with 0.040-inch-thick was 74.9 lbs, and with 0.050-inch-thick was 103.4 lbs. The remaining climbing drum peel specimens which had been intended for control are now considered machined specimens exposed to lab for 6 months and were tested along with the 6-month tropical.

The remaining 6-month tropical tests performed were beam shear, flatwise compression, insert torque and pullout, and sealant durometer. In general the testing proceeded smoothly. All of the specimens tested exceeded the guidelines set in the

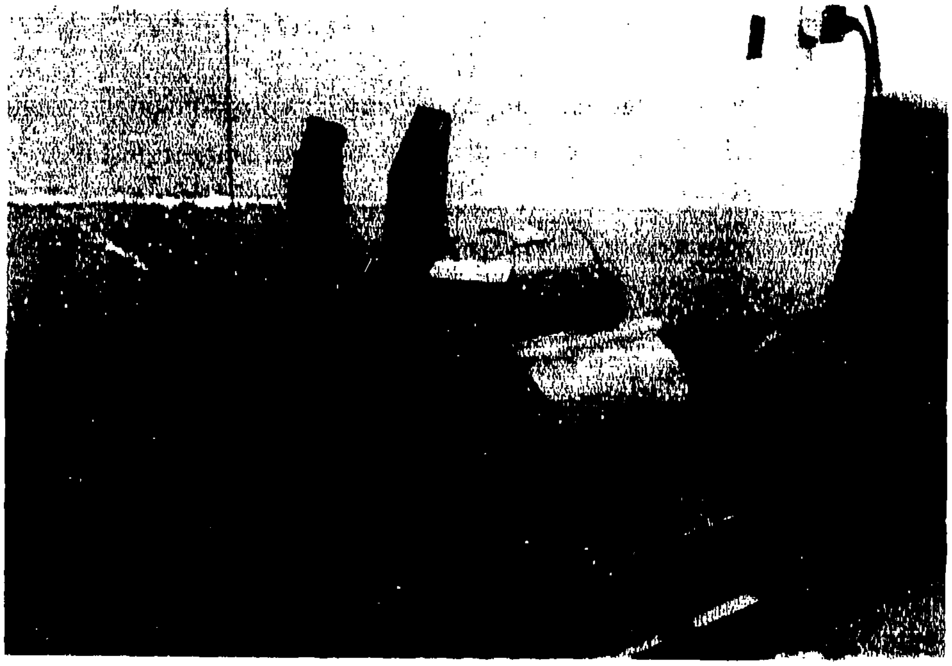


Figure 27. Belt Sander Used to Remove Paint from Flatwise Tension Specimens.

Figure 28. Paint Being Removed from Flatwise Tension Specimens.

appropriate ASTM Specifications for shelter materials and processes except panel No. 9's 0.040-inch-thick inner aluminum skin to Kraft paper core average peel strength of 6.3 in-lb/in. Note that this panel was exposed to the tropics for 6 months. It was observed that the results of the machined specimens exposed to the lab for 6 months were lower than both the control and 6-month tropical. Section 10 "Discussion of Results" will present more on this subject.

It appeared that all the difficulties with logistics, equipment, supplies, etc., had been resolved and no changes were planned for the next visit. Some of the test fixtures were to be returned to Hexcel but would be sent back to Panama before the next scheduled withdrawal.

SECTION 6
ONE-YEAR WITHDRAWAL

Prior to the visit for the 1-year withdrawal, the required test fixtures and supplies were sent to the TTC. Also prior to the visit, arrangements were made with the Facility Engineering Department to reserve the bandsaw and hopefully the same assistant. The motor pool was also contacted and a truck was reserved for transporting the panels from the outdoor tropic exposure test site at Chiva-Chiva. It seemed that from past experience that all was planned in advance and the work would proceed without difficulty. For the most part this was true, but some difficulties were encountered and are discussed later in this section.

In early October 1984, the same representatives from NATICK, UDRI, and Hexcel arrived in Panama City, Panama. Once at the TTC, the fixtures and supplies previously shipped were inspected. All had arrived and were in good condition.

6.1 PANEL WITHDRAWAL FROM CHIVA-CHIVA EXPOSURE SITE

Upon arrival at Chiva-Chiva, all of the panels were visually inspected and coin tap tested on both sides. The green paint on the top side had begun to discolor or fade but was not peeling or chipping. Fungus had now covered the entire surface on the white side as shown in Figure 29. The paint had continued to peel from the zinc plated steel latches on the green side only and had begun to corrode as shown in Figure 30.

All panels were then coin tap tested on both sides as shown in Figure 31. Special attention was given to the areas around the "dings" found on Nomex panels during uncrating. Also, attention was given around the holes which were to simulate damage. No delaminations were indicated by coin tap testing in any of the panels. Also, all of the humidity indicators were checked and all were blue indicating no water or moisture intrusion. Many of the panel numbers had faded, so each was renumbered in the same location on the panel white side.

As scheduled five panels were then removed from the racks and transported back to the TTC Materials Lab and weighed. Panel identification and weights are shown in Table 8. The sealed panels did not have any significant weight change. However, the panels with no polysulfide sealant gained a significant amount of weight, in particular the Kraft paper core panel. At the time it was believed that this was the first significant

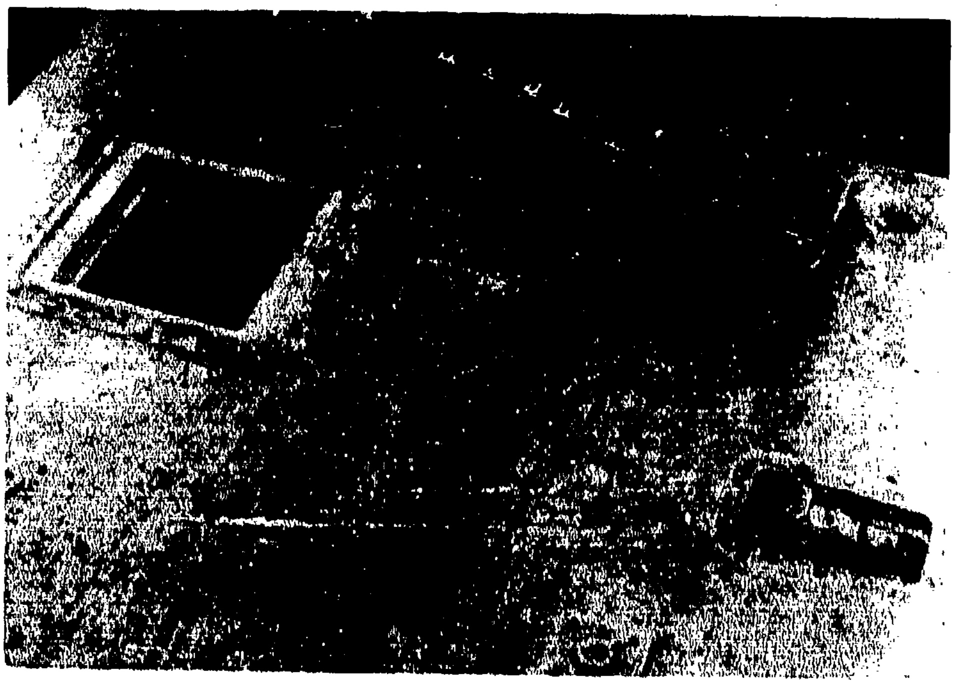


Figure 29. Fungus Covering the White Side of Exposed Panel After 1 year of Tropical Exposure.

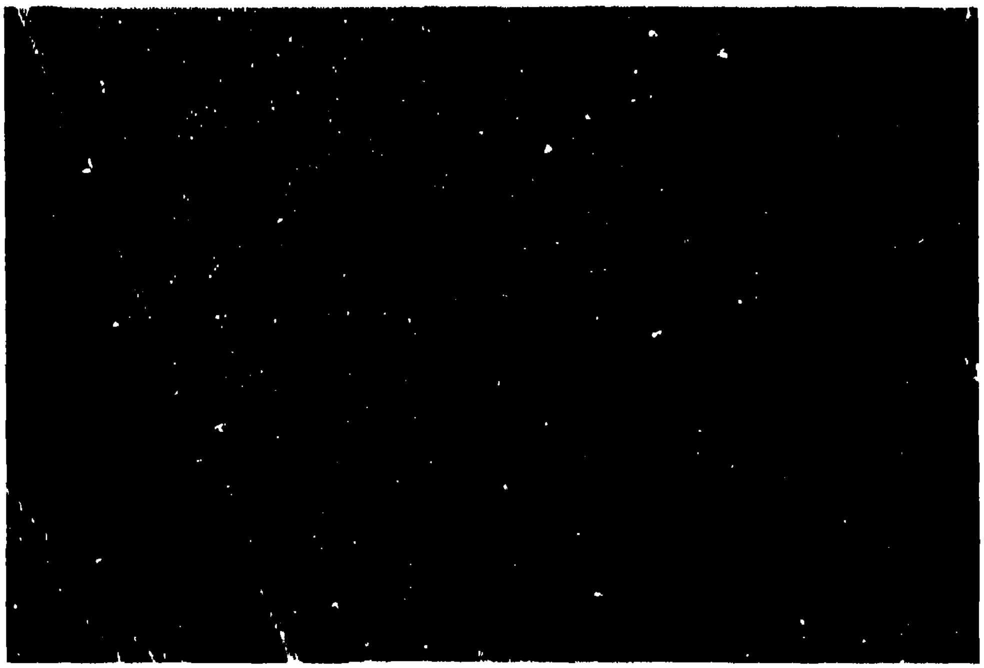


Figure 30. Paint Peeling and Corrosion on Top Side Latch After 1 Year of Tropical Exposure.

Figure 31. Coin Tap Testing After 1 Year Tropical Exposure.

effect of tropical exposure. The panels were then transported a short distance to the Facility Engineering Department (FED) for machining.

TABLE 8

ONE-YEAR WITHDRAWAL PANEL IDENTIFICATION AND WEIGHTS

Panel Number	Type Core	Configuration	Weights, lb		Weight Pick-Up (lb)
			Initial	1 Year	
3	Kraft	Standard	97.00	96.91	-0.09
10	Kraft	Hardware	106.75	106.80	0.05
16	Kraft	Damaged	95.13	95.31	0.18
21	Kraft	No Sealant	96.15	98.40	2.25
31	Nomex	No Sealant	101.76	102.56	0.80

6.2 PANEL LAYOUT AND SPECIMEN MACHINING

Upon arrival at the FED, the panels were washed with warm water and dried with paper towels. The dirt and fungus were easily removed. Once washed, the white paint was nearly returned to its original finish. The panels were then laid out according to the drawings prepared on the original visit. Each specimen was carefully identified for panel number, type test, location within the panel, specimen number, and where appropriate core orientation (i.e., L or W).

Since the Kraft paper core panel with no polysulfide sealant around panel perimeter had gained so much weight, the cutting began with that panel. Everyone was anxious to see the extent of moisture within the panel. The initial cut must be through one of the closeout channels around the periphery of the panel. As soon as this cut was made, a significant quantity of water ran from the channel. As cutting continued, close attention was given the inside of the channel and the edges of the now exposed core. It appeared that most, and maybe all, of the water had been sucked into the channel at the corners. After the panel was cut, water was poured in the closeout and, indeed, it would run out of the mitred joint of two channels. When cutting the panel with Nomex core, water also ran from the channel but, not as much as with the Kraft paper core panel. After machining, the corner of this panel was also checked and the leakage was found to be far less.

Specimen machining continued and as before each was placed in a sealed plastic bag as soon as possible. It took 2 full days to complete the panel layout and specimen machining. While machining was progressing some of the bags containing the specimens were delivered to the Materials Lab so that preparations for test could begin.

6.3 MECHANICAL PROPERTY TESTING

Upon arrival at the TTC Materials Lab, the specimens were deburred and then the appropriate physical dimensions were taken and recorded in the laboratory notebook. The specimens were then returned to the plastic bags until the tests were performed.

Knowing that flatwise tension would be one of the most time consuming tests, specimens were prepared and bonded as quickly as possible. It was hoped that by using an adhesive with quick room temperature cure and by removing the paint that testing would proceed smoothly and, indeed, it did. However, it soon became obvious that not enough time was given for this visit. The number of individual specimens tested during the 6-month withdrawal was 231. For the 1-year withdrawal there were 346 test specimens. The same length of time was allotted for both visits. This meant that testing went well into the night on most every day. Fortunately, the materials and procedures used for flatwise tension were working well and very few specimens required rebonding. The number of flatwise tension specimens did present a problem. A group of specimens was tested, the blocks were cleaned, then another set bonded and tested, and so on. The blocks were cleaned by burning off the adhesive in a muffle furnace. This furnace was very small and only a few blocks at a time could be cleaned. A larger furnace was located near the Facility Engineering Department which was a considerable help.

Despite the problems of logistics with flatwise tension and the overwhelming number of tests to perform in a short time, all went well. All the planned tests were completed, the data was tabulated and entered into the laboratory notebook. Also, all data met the minimum standards set in the ASTM Specifications for shelter materials and processes, including climbing drum peel.

Some of the fixtures were to be returned to Hexcel, but would again be returned to Panama before the next scheduled withdrawal.

SECTION 7
TWO-YEAR WITHDRAWAL

Prior to the visit for the 2-year withdrawal, two important decisions were made. First, additional loading blocks for flatwise tension would be machined and sent to the Materials Lab at TTC in advance. It is obvious that this test has caused more difficulties than any other. Improvements have been made before and during each visit and hopefully this would finally resolve all the difficulties. Second, another representative from UDRI would make the trip to Panama and assist in the testing and data reduction. It was hoped that with additional flatwise tension loading blocks and personnel that the work could be completed efficiently and without being a burden on TTC personnel and their families. Also, prior to the visit all the test fixtures and required supplies were sent to TTC. In addition the Facility Engineering Department and motor pool were notified.

In late September 1985, the same representatives from NATICK, UDRI, and Hexcel plus the additional representatives from UDRI arrived in Panama City, Panama. Once at the TTC Materials Lab, all fixtures and supplies were inspected and found to be in good condition.

7.1 PANEL WITHDRAWAL FROM CHIVA-CHIVA EXPOSURE SITE

Upon arrival at Chiva-Chiva all the panels were visually inspected and coin tap tested on both sides. The green paint had continued to fade but no peeling or chipping was observed. Fungus had continued to cover the entire white side of the panel and algae had begun to appear on the bottom edge of the green side as shown in Figure 32. No significant change was noted on the latches; that is, the paint on the green side had peeled and some corrosion was evident, but the latches on the white side looked good.

All panels were coin tap tested on both sides. Again special attention was given to the areas around the "dings" and the simulated damage holes. No delaminations were indicated by coin tap testing. All humidity indicators were checked and were blue. All panels were also renumbered as done during the 1-year withdrawal.

A surface pyrometer was taken to Chiva-Chiva and the top and bottom skin temperature were measured under varying conditions throughout the day. The skin temperatures recorded are shown in Table 9.

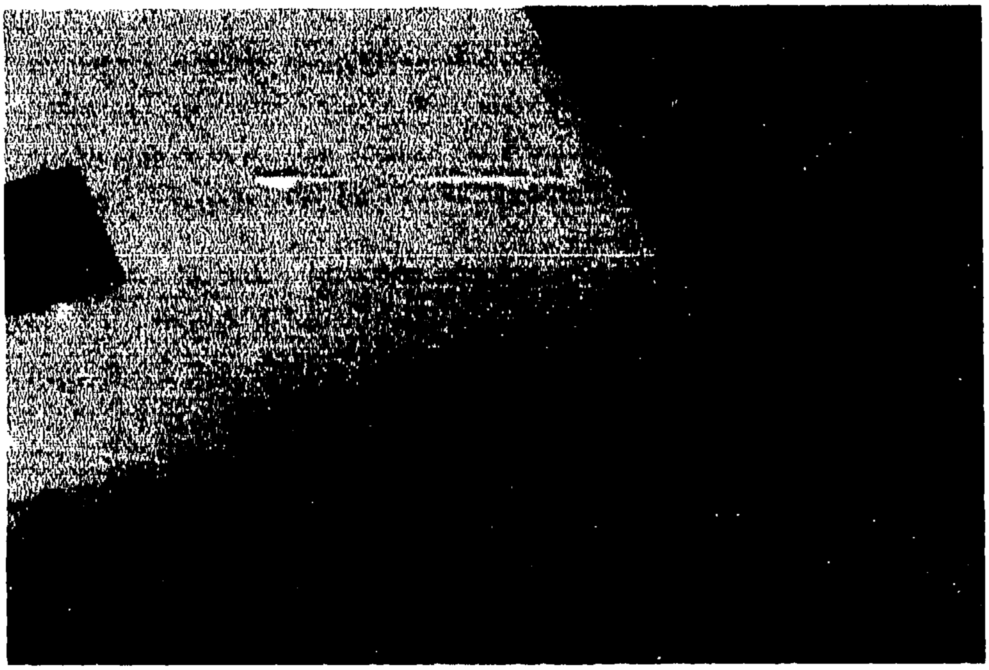


Figure 32. Algae on Green Side of Exposed Panels After 2 Years of Tropical Exposure.

TABLE 9

SKIN TEMPERATURES UNDER VARYING CONDITIONS

Skin	Time	Condition	Temperature
Top	9:00 A.M.	Sunny	140°F
Bottom	9:00 A.M.	Sunny	80°F
Top	10:00 A.M.	Sunny	150°F
Bottom	10:00 A.M.	Sunny	80°F
Top	2:00 P.M.	Cloudy	95°F
Bottom	2:00 P.M.	Cloudy	80°F

As scheduled, five panels were then removed from the racks and transported back to the TTC Materials Lab and weighed. Panel identification and weights are shown in Table 10. All panels had gained weight but none significantly. The panels were then transported a short distance to the Facility Engineering Department for machining.

TABLE 10

TWO-YEAR WITHDRAWAL PANEL IDENTIFICATION AND WEIGHTS

Panel Number	Type Core	Configuration	Weights, lb		Weight Pick-up (lb)
			Initial	2 Year	
4	Kraft	Standard	97.15	97.30	0.15
11	Kraft	Hardware	114.00	114.20	0.20
17	Kraft	Damaged	97.31	97.70	0.39
22	Kraft	No Sealant	96.00	96.50	0.50
25	Nomex	Standard	101.52	102.05	0.53

7.2 PANEL LAYOUT AND SPECIMEN MACHINING

Upon arrival at the FED, the panels were washed with warm water and dried with paper towels. The dirt, fungus, and algae were easily removed. Once washed, the white side nearly returned to its original luster but the green remained faded. The panels were then laid out according to the drawings prepared on the original visit. Each specimen was carefully identified for panel number, type test, location within the panel, specimen number, and where appropriate the core orientation (i.e. L or W).

Specimen machining proceeded and special attention was given to the closeouts of each panel, in particular that of the panel without polysulfide sealant. No water was observed in any of the closeouts. As specimen machining progressed, each was placed in sealed plastic bags and periodically groups were taken to the Materials Lab so that preparations for test could begin. No significant problems were encountered during specimen machining.

7.3 MECHANICAL PROPERTY TESTING

As soon as specimens were delivered to the Materials Lab, each was deburred and the appropriate physical dimensions were taken and recorded in the laboratory notebook. The specimens were returned to the plastic bags until the tests were performed.

As quickly as possible preparations began for flatwise tension tests. After the physical dimensions were taken, the paint was carefully removed and the loading blocks bonded. For the first time all went well with the flatwise tension tests. In fact, all tests proceeded with no major problems. The tests were conducted, the data tabulated, and recorded in the laboratory notebook. Again the data obtained met the minimum standards set in the ASTM Specifications for shelter materials and processes with the exception of Panel No. 11 which had an average peel value of 6.1 in-lb/in for the 0.040-inch-thick inner aluminum skin to Kraft paper core. See Section 10 "Discussion of Results."

Some of the test fixtures were returned to Hexcel and UDRI, but would again be returned to Panama before the next scheduled withdrawal.

SECTION 8
THREE-YEAR WITHDRAWAL

Prior to the 2-year withdrawal, two decisions were made which proved to be invaluable. The first and probably the most significant was to fabricate enough tension blocks to nearly complete all flatwise tension without cleaning and rebonding. The second was to take additional personnel. Since everything went smoothly during that visit it was decided not to change. Also, prior to this visit, all the test fixtures and supplies were sent to TTC. Also TTC personnel notified the Facility Engineering Department and the motor pool.

In late September 1986, the original representatives from the NATICK, UDRI, and Hexcel, plus an additional representative from UDRI, arrived in Panama City, Panama. As before, acquaintances were renewed, paperwork was completed, and the fixtures and supplies inspected.

8.1 PANEL WITHDRAWAL FROM CHIVA-CHIVA EXPOSURE SITE

Once again upon arrival at Chiva-Chiva all the panels were visually inspected and coin tap tested on both sides. The green paint had continued to fade but was not peeling or chipping. The algae which had begun to appear along the lower edge on the green side had now expanded in area and was beginning to grow along the edge of some panels as shown in Figure 33. The fungus on the white side had begun to thicken somewhat as shown in Figure 34. No significant change was observed on the latches. The paint peeling observed after 6 months exposure and the corrosion seen after 1 year exposure had not worsened. All of the humidity indicators were blue.

Each panel was coin tap tested on both sides. Again special attention was given to the areas around the "dings" and the simulated damage holes. No delaminations were indicated by coin tap testing. While tap testing around the simulated damage holes, it was observed that the Nomex paper core showed no significant discoloration or deterioration. In contrast, much of the exposed Kraft paper core had been eaten away. It was suspected that much of this was from insects, although weathering may have contributed to it. Water from an earlier rain storm could be seen in the core cells with simulated damage in the top skin. Insects had taken residence in the cells with simulated damage in the bottom skin. All of the remaining panels were renumbered.

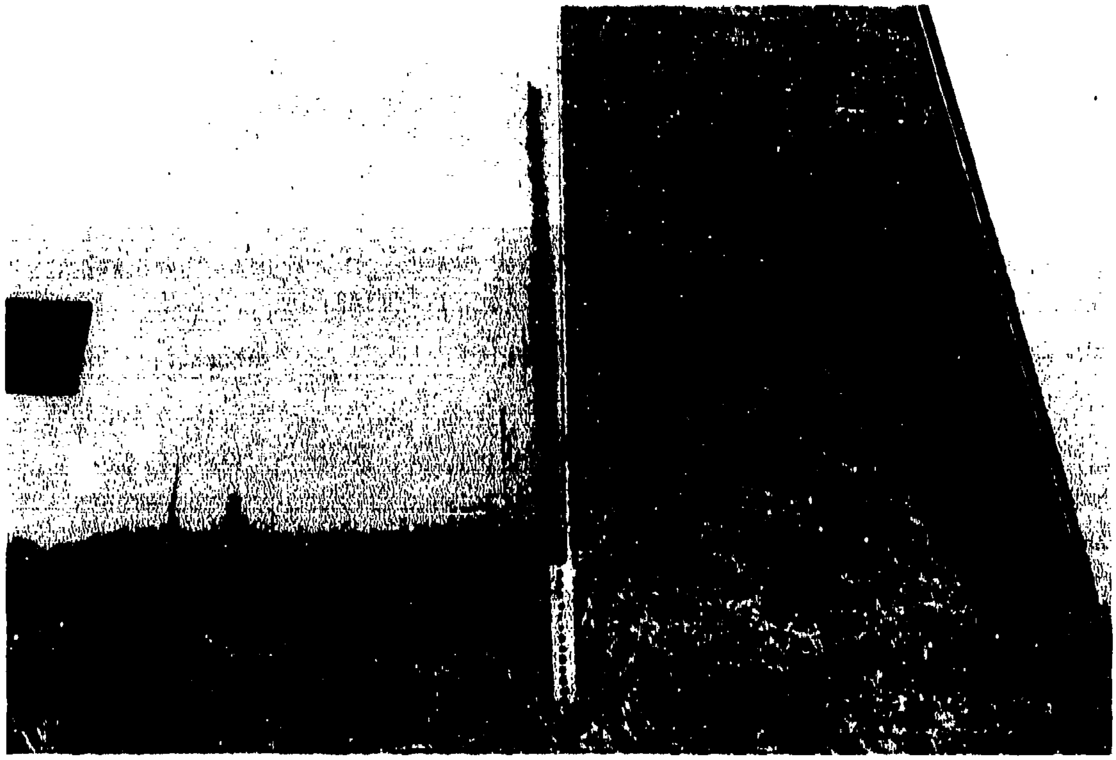


Figure 33. Algae on Green Side of Panel After 3 Years of Tropical Exposure.

Figure 34. Fungus on White Side of Panel After 3 Years of Tropical Exposure.

As scheduled four panels were removed from the racks and transported back to the TTC Materials Lab and were weighed. Panel identification and weights are shown in Table 11. Two of the panels gained what may be considered a significant amount and special attention was given to these during specimen machining. The panels were then transported a short distance to the Facility Engineering Department.

TABLE 11
THREE-YEAR WITHDRAWAL PANEL IDENTIFICATION AND WEIGHTS

Panel Number	Type Core	Configuration	Weights, lb		Weight Pick-up (lb)
			Initial	3 Year	
5	Kraft	Standard	94.56	96.40	1.84
12	Kraft	Hardware	108.75	108.75	0.00
18	Kraft	Damaged	94.70	94.95	0.25
23	Kraft	No Sealant	95.65	96.90	1.25

8.2 PANEL LAYOUT AND SPECIMEN MACHINING

Upon arrival at the FED, the panels were washed with warm water and dried with paper towels. The dirt, fungus, and algae were not as easily removed as after previous exposures. The white side had become stained from the fungus and the green side was noticeably faded. After cleaning the panels were laid out according to the drawings prepared during the original withdrawal. Each specimen was carefully identified for panel number, type test, location within the panel, specimen number, and where appropriate the core orientation (i.e., L or W).

Specimen machining proceeded and special attention was given to the closeout extrusions; in particular, those from the two panels which had gained a significant amount of weight. Once again when these extrusions were cut, water began to pour from them. Also as done previously, each specimen was placed in sealed plastic bags as quickly as possible and periodically groups were taken to the Materials Lab so that preparations for test could begin.

The native Panamanian who had assisted during the previous visits was not available. New personnel were supplied by FED and were as helpful and cooperative as the previous. Specimen machining proceeded without any problems.

8.3 MECHANICAL PROPERTY TESTING

As soon as specimens were delivered to the Materials Lab each was deburred and the appropriate physical dimensions taken and recorded in the laboratory notebook. The specimens were then returned to the plastic bags until the tests were conducted.

The same schedule used during the 2-year withdrawal was followed. Once again with the additional flatwise tension loading blocks and personnel, testing proceeded smoothly. Except for the climbing drum peel strength of 6.5 in-lb/in for Panel No. 12's 0.040-inch-thick inner aluminum skin to Kraft paper core, all data met the minimum standards set in the ASTM Specifications for shelter materials and processes as listed in Table 4. See Section 10, "Discussion of Results." All testing was completed, the data tabulated and recorded in the laboratory notebook.

Some additional observations were noted. During the torque and pull-out tests on the inserts, it was observed that insects had taken up residence in about half of those on the bottom side of the panel and none in those on the top side. Also, during coin tap testing of the panels at Chiva-Chiva, it was observed that some of the exposed core in the simulated damaged Kraft paper panels had been eaten away. Figure 35 shows a cross-section of a simulated damage hole in the top skin of Panel No. 18. Upon close examination, some discoloration of the core could also be seen. However, the core looked good and dry only one or two cells beyond the hole area, indicating excellent water migration resistance.

Also, not since the original visit was anything done with the panels being stored in the controlled environment of the laboratory. Thus, for the record these panels were visually inspected and coin tap tested on both sides. As one would expect the paint on both sides looked the same as it was when uncrated and no delaminations were indicated by tap testing.

Some of the test fixtures were returned to Hexcel and UDRI, but would again be returned to Panama before the 5-year scheduled withdrawal.

Figure 35. Cross Section of Simulated Damage Hole in Top Skin.

SECTION 9
FIVE-YEAR WITHDRAWAL

As described in Section 4 of this report, the panels intended for long term tropic exposure were placed in racks at an exposure site identified as Chiva-Chiva. This particular exposure site was a secure area; however, after about 4 years of exposure at that site the security was discontinued. The panels were moved, by USATTC personnel, to a site within the confines of Fort Clayton. The panels were again placed in the aluminum racks and positioned at a 30° angle to the horizontal and facing east to assure proper water drainage and maximum sun (solar) exposure.

Prior to the 5-year withdrawal, flatwise tension blocks, all test fixtures, and supplies were sent to TTC. Due to the large number of tests to be conducted, additional flatwise tension blocks had been manufactured to minimize cleaning. Experience from past withdrawals had shown that having sufficient tension blocks to nearly complete all flatwise tension tests without cleaning was a valuable time saver.

In late October 1988, one representative from NATICK and two from UDRI arrived in Panama City, Panama. One UDRI representative stayed for about one-half of the time required to complete the 5-year withdrawal. Just prior to his departure, the representative from Hexcel arrived in Panama and stayed for the remainder of the time required to complete the withdrawal. As before, upon arrival acquaintances were renewed, paperwork was completed, and the fixtures and supplies inspected.

9.1 PANEL WITHDRAWAL FROM FORT CLAYTON EXPOSURE SITE

Upon arrival at the Fort Clayton exposure site, all panels were visually inspected and coin tap tested on both sides. A view of the exposure site is shown in Figure 36. The green paint which had begun to fade early in the tropic exposure test had now stabilized and was similar to that after 3 years exposure. No peeling or chipping was observed except on the zinc plated steel latches on the green side only as shown in Figure 37, which had initially been observed after 6 months exposure. The algae which had begun to appear along the lower edge on the green side after 2 years of exposure had now spread and covered much of some panels as shown in Figure 38. The fungus on the white side had continued to thicken as shown in Figure 39. All of the humidity indicators were blue.

Figure 36. View of Fort Clayton Exposure Site.

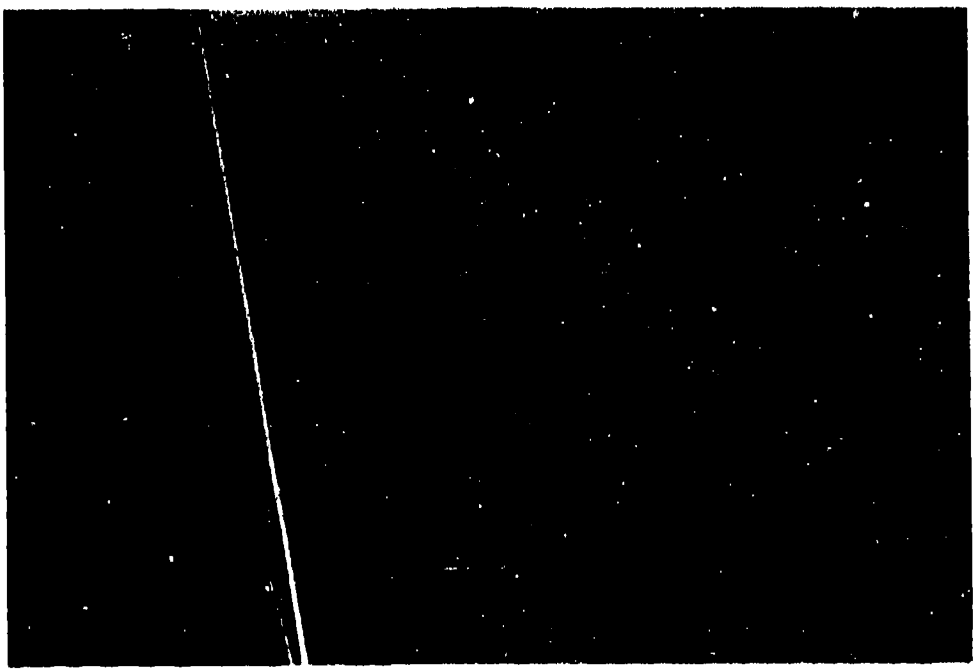


Figure 37. Paint Peeling and Corrosion on Top Side Latch After 5 Years of Tropical Exposure.

Figure 38. Algae on Green Side of Panel After 5 Years of Tropical Exposure.

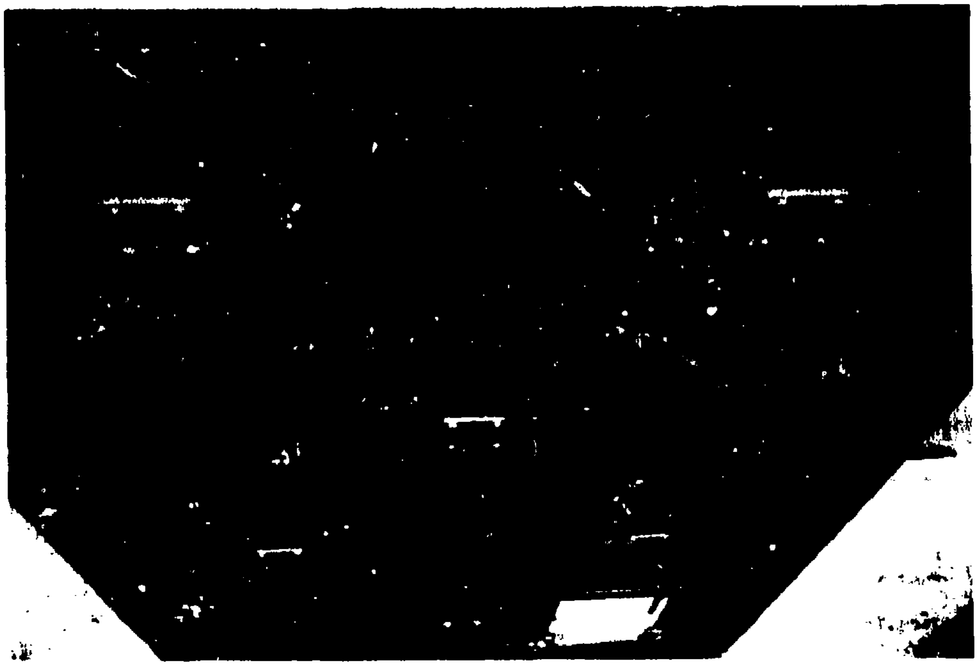


Figure 39. Fungus on White Side of Panel After 5 Years of Tropical Exposure.

Each panel was coin tap tested on both sides. Again special attention was given to the areas around the "dings" and the simulated damage holes. No delaminations were indicated by coin tap testings. The Kraft paper core exposed by the simulated damage had continued to deteriorate and was eaten away by insects. The Nomex paper core showed only slightly discoloration and deterioration.

The eight tropical exposure panels were removed from the racks and transported back to the TTC Materials Lab. These eight panels plus the three which have been stored in the controlled environment in the TTC lab were weighed. Panel identification and weights are shown in Table 12. Panel No. 32 gained what may be considered a significant amount and special attention was given to this panel during specimen machining. The panel, No. 32, was one without polysulfide sealant around the perimeter between the skin(s) and frame members. The three panels stored in the controlled environment were also coin tap tested on both sides.

TABLE 12

FIVE-YEAR WITHDRAWAL PANEL IDENTIFICATION AND WEIGHTS

Panel Number	Type Core	Configuration	Weights, lb		Weight Pick-up (lb)
			Initial	5 Year	
6	Kraft	Standard	96.75	96.75	0
7(1)	Kraft	Standard	95.69	95.80	0.11
13	Kraft	Hardware	109.50	109.60	0.10
14(1)	Kraft	Hardware	108.00	108.10	0.10
19	Kraft	Damaged	96.25	97.15	0.90
20(1)	Kraft	Damaged	96.00	96.20	0.20
24	Kraft	No Sealant	96.13	96.20	0.07
26	Nomex	Standard	101.04	101.20	0.16
28	Nomex	Hardware	111.16	111.25	0.09
30	Nomex	Damaged	99.84	100.50	0.64
32	Nomex	No Sealant	100.98	102.95	1.97

NOTE: (1) Stored in TTC laboratory controlled environment for 5 years.

9.2 PANEL LAYOUT AND SPECIMEN MACHINING

The panels were then transported a short distance to the FED machine shop. The panels were then washed with warm water and dried with paper towels. Although it required hard scrubbing the dirt was removed. The white side had become stained from the fungus and the green side was stained from the algae and noticeably faded. After cleaning the panels were laid out according to the drawings prepared during the original withdrawal. Each specimen was carefully identified for panel number, type test, location within the panel, specimen number, and where appropriate the core orientation (i.e., L or W).

Specimen machining proceeded and special attention was given the closeout extrusions; in particular, those from panels which had gained a significant amount of weight. Panel No. 32, a Nomex core with no polysulfide sealant, not only had some water in the extrusion but moisture was also visible in the honeycomb in what was the lower edge of the panel as it was stored in the rack. No moisture was observed in the Kraft paper panel with no polysulfide sealant. As was done during previous withdrawals, specimens were placed in sealed plastic bags as quickly as possible and periodically groups were taken to the TTC Materials Lab so that preparations for test could begin.

Once again as in previous visits, native Panamanians assisted in the machining and were very helpful and cooperative. Specimen machining proceeded without any problems other than the magnitude of machining 11 panels into test specimens.

9.3 MECHANICAL PROPERTY TESTING

Once the specimens were delivered to the Materials Lab, each was deburred and the appropriate physical dimensions taken and recorded in the laboratory notebook. The specimens were then returned to the plastic bags until the tests were conducted.

The same general testing schedule successfully used during the 2- and 3-year withdrawals was followed. Although the testing went well, the number of tests from the 11 panels machined was nearly overwhelming. Tests included 237 climbing drum peel, 228 beam shear, 143 flatwise compression, and 126 flatwise tension. It took a considerable length of time to deburr, dimension, and record data in the notebook. The paint was removed from the flatwise tension specimens and the tensile loading blocks were bonded. As soon as one group of tension specimens were completed, the blocks were removed and rebonded on the opposite side to the next group of specimens. Except for a few individual climbing drum peel test specimens, all data met the minimum standards set in the ASTM Specifications for shelter materials and processes as listed in Table 4. All testing was completed, the data tabulated and recorded in the laboratory notebook.

Upon completion of the testing, all of the test fixtures were returned to UDRI or Hexcel.

SECTION 10
DISCUSSION OF RESULTS

The long term tropic environmental exposure of rigid wall honeycomb sandwich panels was intended to determine the effect of that exposure on physical and mechanical properties over a 5-year period. All visual, physical, and mechanical tests were completed beginning October 1983 and ending November 1988. Results include those for control, 6-month control, machined specimens exposed to lab for 6 months, 1 year, 2 years, 3 years, and 5 years tropical exposure. The machined specimens exposed to lab for 6 months resulted from difficulties with the USATTC Instron test machine while testing compression specimens during the initial vist to Panama and is discussed in detail in Sections 4 and 5 of this report.

Upon withdrawal from tropical exposure each panel was subjected to a variety of visual, physical, and mechanical tests. Details of these tests, test methods, and requirements are discussed in detail in Section 3 of this report.

10.1 VISUAL INSPECTION, TAP TESTING, AND PANEL WEIGHTS

All panels were visually inspected, coin tap tested, and weighed before being placed in racks at the Chiva-Chiva test site, tested for control data, or stored in the controlled environment in the Materials Lab at the Tropic Test Center.

Initially all the panels looked in good shape except for the "dings" in the Nomex panels caused by improper packing for shipment to Panama. These "dings" were from the humidity indicators from the bottom side of one panel striking the top side of another. Close attention was given to these areas and as expected no adverse effects, including no delaminations, resulted from these "dings" over the 5 years of exposure.

After 6 months of tropical exposure, some fungus growth was noted on the bottom side of each panel. After 1 year the fungus had totally covered the bottom and then thickened after 2 years and stained the white paint after 3 years. Also, after 2 years exposure algae began to appear on the lower edge of the top side of some panels and spread upward after 3 years. No attempt was made to identify the particular type of fungus or algae. Speculation that fungus would grow on the bottom and algae on the top is that of experienced personnel at the Tropic Test Center. Upon withdrawal both surfaces were washed with warm water and both the fungus and algae were easily removed except for the staining on the bottom side. The white side of each panel would return nearly to its original luster but the green side became faded, in particular after 3 and 5 years. The only paint peeling or corrosion noted was that on the zinc plated steel latches.

The embedded humidity indicators in each panel are designed to change color, from blue to pink, if the humidity reaches 70, 80, and 90% in those identified areas. After 5 years, none have changed color. Since the process is reversible, TTC personnel were requested to periodically inspect them. They also have reported no color change.

All panels were thoroughly coin tap tested on both sides during the initial visit to Panama. Upon each withdrawal up to 3 years, all panels in the racks at Chiva-Chiva were then also coin tap tested; and during the 5th year withdrawal, they were coin tap tested at the Fort Clayton exposure site. During the 3- and 5-year withdrawal the panels being stored in controlled conditions were also tap tested. Special attention was given to the areas around the "dings" and the holes which simulate damage. No delaminations were detected by coin tap testing.

All panels were weighed initially and then reweighed upon withdrawal. The weights of the Kraft paper core panels are shown in Table 13 and the Nomex paper core in Table 14. Individual panel weights ranged from a minimum of 95 pounds for a standard panel to a maximum of 115 pounds for a hardware panel. Panel Nos. 21, 23, and 32, manufactured purposely without applying polysulfide sealant around the panel perimeter frame and within the four individual unwelded mitred frame joints, and standard Panel No. 5 had gained what was considered a significant amount. When cutting these panels into specimens for mechanical property tests, water ran from the closeout perimeter frame channeling. It is suspected that little moisture actually penetrated into the interior core of these panels. It is suspected that as the sun shines on the panel, the air in the closeouts expands. If a rain storm suddenly appears, which it often does, the panel rapidly cools, the air contracts and a vacuum is created in the closeout which sucks water in through the corners if they are not properly sealed. Note that all these panels were constructed with a deployable roof panel perimeter design that has unwelded mitred joints. In contrast the fixed roof, walls and floor have a welded joint perimeter design to take the structural transit loads seen by this ISO shelter/container.

TABLE 13

KRAFT PAPER CORE PANEL WEIGHTS, POUNDS

Panel	Weight		Exposure
	Initial/Final	Change	
#1 Kraft, Standard	97.25/---	---	Control
#8 Kraft, Hardware	111.25/---	---	Control
#2 Kraft, Standard	95.15/95.09	-0.06	6 Mo Tropical
#9 Kraft, Hardware	114.63/114.81	0.18	6 Mo Tropical
#15 Kraft, Damaged	94.75/94.81	0.06	6 Mo Tropical
#3 Kraft, Standard	97.00/96.91	-0.09	1 Yr Tropical
#10 Kraft, Hardware	106.75/106.80	0.05	1 Yr Tropical
#16 Kraft, Damaged	95.13/95.31	0.18	1 Yr Tropical
#21 Kraft, No Sealant	96.15/98.40	2.25(1)	1 Yr Tropical
#4 Kraft, Standard	97.15/97.30	0.15	2 Yr Tropical
#11 Kraft, Hardware	114.00/114.20	0.20	2 Yr Tropical
#17 Kraft, Damaged	97.31/97.70	0.39	2 Yr Tropical
#22 Kraft, No Sealant	96.00/96.50	0.50	2 Yr Tropical
#5 Kraft, Standard	94.56/96.40	1.84(1)	3 Yr Tropical
#12 Kraft, Hardware	108.75/108.75	0.00	3 Yr Tropical
#18 Kraft, Damaged	94.7/94.95	0.25	3 Yr Tropical
#23 Kraft, No Sealant	95.65/96.90	1.25(1)	3 Yr Tropical
#6 Kraft, Standard	96.75/96.75	0.00	5 Yr Tropical
#7 Kraft, Standard	95.69/95.80	0.11	5 Yr Control
#13 Kraft, Hardware	109.50/109.60	0.10	5 Yr Tropical
#14 Kraft, Hardware	108.00/108.10	0.10	5 Yr Control
#19 Kraft, Damaged	96.25/97.15	0.90	5 Yr Tropical
#20 Kraft, Damaged	96.00/96.20	0.20	5 Yr Control
#24 Kraft, No Sealant	96.13/96.20	0.07	5 Yr Tropical

NOTE: (1) Water in close-out channel.

TABLE 14
NOMEX PAPER CORE PANEL WEIGHTS, POUNDS

Panel	Weight		Exposure
	Initial/Final	Change	
#27 Nomex, Hardware	111.31/---	---	Control
#29 Nomex, Damaged	99.52/---	---	Control
#31 Nomex, No Sealant	101.76/102.56	0.80	1 Yr Tropical
#25 Nomex, Standard	101.52/102.05	0.53	2 Yr Tropical
#26 Nomex, Standard	101.04/101.20	0.16	5 Yr Tropical
#28 Nomex, Standard	111.16/111.25	0.09	5 Yr Tropical
#30 Nomex, Damaged	99.84/100.50	0.66	5 Yr Tropical
#32 Nomex, No Sealant	100.98/102.95	1.97(1)	5 Yr Tropical

NOTE: (1) Moisture was visible in lower edge of panel and water was found within the close-out channel.

10.2 FLATWISE COMPRESSION

Flatwise compression test specimens were machined from each panel configuration. Except for hardware panels, each configuration is divided into quarters and at least three specimens are located in each of those quarters. Specimen location for all panels are shown in Figures 5 to 8. Minimum values of compressive strength for honeycomb sandwich panels used in shelter construction have been established and are presented in ASTM E1091. The minimum compression strength for Type IV honeycomb core is 404 psi. All of the compression specimens exceeded these minimum guidelines. However, the average compression values of the Kraft paper honeycomb machined specimens (that were inadvertently stored for 6 months unpackaged and exposed to the TTC lab) were the lowest of all the panel compression values. In fact, they were up to 24% lower than those of the control (i.e., base-line) unexposed and 6 month tropics exposed Kraft paper panels. In contrast, the average compression values of the Nomex honeycomb machined specimens (that were inadvertently stored for 6 months unpackaged and exposed to the TTC lab) were basically the same as those of the base-line unexposed Nomex panels. After 2 years of tropical exposure, the compression strengths measured are at least as high as those measured on the control specimens. After 3 and 5 years exposure, the compression strengths for panels with Kraft paper core may be declining slightly, but still met minimum specification values. A summary of the Kraft paper core compression strengths are shown in Table 15 and the Nomex paper core strengths in Table 16.

10.2.1 Compression Near Simulated Damage

The flatwise compression test may be one which is very sensitive to the effect of environmental exposure on sandwich panel mechanical properties. For this reason compression specimens are located very close to the holes simulating damage. The simulated damage panels are divided into quarters, "A" having a hole in the top skin, "B" having no hole, "C" having a hole in the bottom skin, and "D" having a hole in both skins. As expected, in most cases the average compression strength from the quarter with no holes is the highest and the quarter with the hole in the top skin only is the lowest. During several visits to the exposure site, water could be seen standing in the cells with a hole in the top skin only. During the panel withdrawal, up to the 2-year exposure, a piece of the panel containing the holes was cut, sealed in a plastic bag, and returned for use as visual aids while presenting the results at appropriate meetings. It is interesting to note that condensation was observed in the bag containing the specimen

TABLE 15
KRAFT PAPER CORE COMPRESSION STRENGTHS

Panel	Exposure	Avg Strength (psi)
#1 Kraft, Standard	None	530
#1 Kraft, Standard	Machined specimens exposed in lab for 6 mos*	433
#2 Kraft, Standard	6 Mo Tropical	517
#3 Kraft, Standard	1 Yr Tropical	609
#4 Kraft, Standard	2 Yr Tropical	523
#5 Kraft, Standard	3 Yr Tropical	513
#6 Kraft, Standard	5 Yr Tropical	525
#7 Kraft, Standard	5 Yr Controlled	461
#8 Kraft, Hardware	None	572
#8 Kraft, Hardware	Machined specimens exposed in lab for 6 mos*	433
#9 Kraft, Hardware	6 Mo Tropical	553
#10 Kraft, Hardware	1 Yr Tropical	560
#11 Kraft, Hardware	2 Yr Tropical	622
#12 Kraft, Hardware	3 Yr Tropical	555
#13 Kraft, Hardware	5 Yr Tropical	531
#14 Kraft, Hardware	5 Yr Controlled	519
#15 Kraft, Damaged	6 Mo Tropical	525
#16 Kraft, Damaged	1 Yr Tropical	530
#17 Kraft, Damaged	2 Yr Tropical	583
#18 Kraft, Damaged	3 Yr Tropical	488
#19 Kraft, Damaged	5 Yr Tropical	485
#20 Kraft, Damaged	5 Yr Controlled	507
#21 Kraft, No Sealant	1 Yr Tropical	587
#22 Kraft, No Sealant	2 Yr Tropical	526
#23 Kraft, No Sealant	3 Yr Tropical	498
#24 Kraft, No Sealant	5 Yr Tropical	531

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 16

NOMEX PAPER CORE COMPRESSION STRENGTHS

Panel	Exposure	Avg Strength (psi)
#27 Nomex, Hardware	None	547
#27 Nomex, Hardware	Machined specimens exposed in lab for 6 mos*	553
#29 Nomex, Damaged	None	503
#29 Nomex, Damaged	Machined specimens exposed in lab for 6 mos*	504
#31 Nomex, No Sealant	1 Yr Tropical	618
#25 Nomex, Standard	2 Yr Tropical	584
#26 Nomex, Standard	5 Yr Tropical	570
#28 Nomex, Hardware	5 Yr Tropical	536
#30 Nomex, Damaged	5 Yr Tropical	540
#32 Nomex, No Sealant	5 Yr Tropical	569

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

with a hole in the top skin only. During the 3-year withdrawal it suddenly occurred that performing compression tests on this area may be of some benefit. Therefore, compression specimens were machined with the holes centered in the 4-inch x 4-inch test area. After 3 years exposure, the compression strengths of these areas in Kraft paper panels ranged from 258 psi for the hole in the top skin, to 405 psi for the hole in the bottom skin. After 5 years exposure, the strengths of these areas in Kraft paper panels ranged from 302 psi for the hole in the top skin, to 467 for the hole in the bottom skin. The compression strengths measured on specimens taken from the same location for the simulated damaged Kraft paper panel stored for 5 years in the controlled lab environment are much higher, in particular the specimen with a hole in the top skin only. The results indicating the effect of simulating damage on Kraft paper core panels are shown in Table 17. The compression values obtained for simulated damaged Nomex panels are very good as evidenced in the results shown in Table 18.

10.3 FLATWISE TENSION

The preparation and testing of the flatwise tension specimens caused the most difficulty of all the tests. The problems included the selection of adhesive used to bond loading blocks, the number of loading blocks, the size of the muffle furnace to clean the blocks, and paint removal. During each visit to Panama, one or more of these problems were solved and finally by the 2-year withdrawal the tests proceeded without difficulty.

Flatwise tension test specimens were machined from each panel configuration. Except for hardware panels, each configuration is divided into quarters and at least three specimens are located in each of those quarters. Minimum values of tensile strength for honeycomb sandwich panels used in shelter construction have been established and are presented in ASTM E1091. The minimum flatwise tensile strength is 306 psi. All of the tension specimens tested up to and including the 5-year tropical exposure exceeded these minimum guidelines. It should be noted that the tensile results for the machined Kraft and Nomex specimens, that were both inadvertently left exposed in the lab for 6 months, were excellent and did not vary significant from the baseline tensile values obtained in the first Panama visit. In contrast the effect on flatwise "compression" results of 6 month lab exposure on the machined Kraft core samples was significant as evidenced by Table 15 results. However, the Nomex core "compression" properties were not affected by this

TABLE 17

EFFECT OF SIMULATED DAMAGE ON COMPRESSION
OF KRAFT PAPER CORE

Panel	Location	Exposure	Avg Strength (psi)
#15 Kraft	"A" Hole Top Skin	6 Mo Tropical	483
#15 Kraft	"B" No Hole	6 Mo Tropical	573
#15 Kraft	"C" Hole Bottom Skin	6 Mo Tropical	519
#15 Kraft	"D" Hole Both Skins	6 Mo Tropical	527
#16 Kraft	"A" Hole Top Skin	1 Yr Tropical	515
#16 Kraft	"B" No Hole	1 Yr Tropical	571
#16 Kraft	"C" Hole Bottom Skin	1 Yr Tropical	515
#16 Kraft	"D" Hole Both Skins	1 Yr Tropical	533
#17 Kraft	"A" Hole Top Skin	2 Yr Tropical	538
#17 Kraft	"B" No Hole	2 Yr Tropical	626
#17 Kraft	"C" Hole Bottom Skin	2 Yr Tropical	584
#17 Kraft	"D" Hole Both Skins	2 Yr Tropical	584
#18 Kraft	"A" Hole Top Skin	3 Yr Tropical	459 258(1)
#18 Kraft	"B" No Hole	3 Yr Tropical	495
#18 Kraft	"C" Hole Bottom Skin	3 Yr Tropical	498 405(1)
#18 Kraft	"D" Hole Both Skins	3 Yr Tropical	501 342(1)
#19 Kraft	"A" Hole Top Skin	5 Yr Tropical	476 302(1)
#19 Kraft	"B" No Hole	5 Yr Tropical	480
#19 Kraft	"C" Hole Bottom Skin	5 Yr Tropical	514 467(1)
#19 Kraft	"D" Hole Both Skins	5 Yr Tropical	470 409(1)
#20 Kraft	"A" Hole Top Skin	5 Yr Controlled	512 516(1)
#20 Kraft	"B" No Hole	5 Yr Controlled	506
#20 Kraft	"C" Hole Bottom Skin	5 Yr Controlled	515 502(1)
#20 Kraft	"D" Hole Both Skins	5 Yr Controlled	493 477(1)

NOTE: (1) Compression specimens with simulated hole.

TABLE 18

EFFECT OF SIMULATED DAMAGE ON COMPRESSION STRENGTH OF NOMEX PAPER CORE

Panel	Location	Exposure	Avg Strength (psi)
#29 Nomex	"A" Hole Top Skin	None	497
#29 Nomex	"B" No Hole	None	476
#29 Nomex	"C" Hole Bottom Skin	None	520
#29 Nomex	"D" Hole Both Skins	None	519
#29 Nomex*	"A" Hole Top Skin	Machined specimens exposed to lab for 6 mos.	501
#29 Nomex	"B" No Hole		476
#29 Nomex	"C" Hole Bottom Skin		553
#29 Nomex	"D" Hole Both Skins		474
#30 Nomex	"A" Hole Top Skin	5 Yr Tropical	588 472(1)
#30 Nomex	"B" No Hole	5 Yr Tropical	550
#30 Nomex	"C" Hole Bottom Skin	5 Yr Tropical	490 488(1)
#30 Nomex	"D" Hole Both Skins	5 Yr Tropical	533 496(1)

NOTE: (1) Compression specimens with simulated damage hole. Minimum requirement 404 psi.

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

inadvertent 6 month lab exposure as evidenced by Table 16. All average Kraft and Nomex panel tensile strengths are presented in Tables 19 and 20.

10.3.1 Repair Patch

Each hardware configuration panel has a repair patch. The repair was done by the manufacturer of the panels at the time of original construction using techniques considered general practice. There are no known guidelines or field tests to perform. It did seem appropriate to cut a flatwise tensile specimen directly over the patch and determine what effect solar and tropical exposure might have upon its strength. Table 21 presents the flatwise tension data obtained. The specimens from the control panel and after 6-month tropical exposure failed through what core remained during the repair. After 1-year tropical exposure, the failure mode changed to debonding between the patch skin and the potting compound, as shown in Figure 40. Also, the strengths were reduced to less than 200 psi and then less than 100 psi after 2 years exposure. Since guidelines do not exist for the flatwise tensile strength of such a repair, it is not known whether this change in failure mode and reduced strength is significant. In addition, these poor results could be a result of a possible error in actual repair adhesive mixing, application and curing, and skin preparation. The tensile strength recovered some after the 3- and 5-year tropical exposure. The tensile strength obtained from the repair patch in the controlled environment was very high, 755 psi. After failure it appeared that the quantity of repair adhesive used in applying this patch was significantly more than that used in other repairs. The flatwise tensile strength for the patches in the Nomex panels remained essentially the same over the 5-year tropical exposure period. Note that the repair adhesive used was a two-part thixotropic room temperature epoxy base adhesive.

10.4 BEAM SHEAR

The beam shear tests probably take the longest time to complete, due to the number of specimens and test speed, but proceeded with little difficulty. Once the test setup was established during the first visit, all the tests went smoothly. Beam shear specimens for test were machined in both the "L" (ribbon) and "W" (transverse) direction of the honeycomb core. The panels were fabricated with the "L" direction of the honeycomb core running the 8-ft length of each. Minimum values of beam shear strengths for honeycomb sandwich panels used in shelter construction have been established and are presented in ASTM E1091. The minimum beam shear strength in the "L" direction is 180 psi and the "W" direction is 113 psi. All of the specimens tested

TABLE 19

KRAFT PAPER CORE FLATWISE TENSILE STRENGTHS

Panel	Exposure	Avg Strength (psi)
#1 Kraft, Standard	None	358
#1 Kraft*, Standard	Machined specimens exposed to lab for 6 mos	353
#2 Kraft, Standard	6 Mo Tropical	503
#3 Kraft, Standard	1 Yr Tropical	394
#4 Kraft, Standard	2 Yr Tropical	397
#5 Kraft, Standard	3 Yr Tropical	485
#6 Kraft, Standard	5 Yr Tropical	451
#7 Kraft, Standard	5 Yr Controlled	429
#8 Kraft, Hardware	None	365
#8 Kraft*, Hardware	Machined specimens exposed to lab for 6 mos	378
#9 Kraft, Hardware	6 Mo Tropical	429
#10 Kraft, Hardware	1 Yr Tropical	416
#11 Kraft, Hardware	2 Yr Tropical	404
#12 Kraft, Hardware	3 Yr Tropical	391
#13 Kraft, Hardware	5 Yr Tropical	448
#14 Kraft, Hardware	5 Yr Controlled	409
#15 Kraft, Damaged	6 Mo Tropical	446
#16 Kraft, Damaged	1 Yr Tropical	391
#17 Kraft, Damaged	2 Yr Tropical	486
#18 Kraft, Damaged	3 Yr Tropical	398
#19 Kraft, Damaged	5 Yr Tropical	474
#20 Kraft, Damaged	5 Yr Controlled	388
#21 Kraft, No Sealant	1 Yr Tropical	470
#22 Kraft, No Sealant	2 Yr Tropical	455
#23 Kraft, No Sealant	3 Yr Tropical	500
#24 Kraft, No Sealant	5 Yr Tropical	419

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 20

NOMEX PAPER CORE FLATWISE TENSILE STRENGTHS

Panel	Exposure	Avg Strength (psi)
#27 Nomex, Hardware	None	361
#27 Nomex*, Hardware	Machined specimens exposed to lab for 6 mos	378
#28 Nomex, Hardware	5 Yr Tropical	386
#29 Nomex, Damaged	None	370
#29 Nomex*, Damaged	Machined specimens exposed to lab for 6 mos	376
#30 Nomex, Damaged	5 Yr Tropical	390
#31 Nomex, No Sealant	1 Yr Tropical	410
#32 Nomex, No Sealant	5 Yr Tropical	399
#25 Nomex, Standard	2 Yr Tropical	414
#26 Nomex, Standard	5 Yr Tropical	409

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 21

FLATWISE TENSION OF REPAIR PATCH

Panel	Exposure	Strength (psi)
#8 Kraft	None	473
#9 Kraft	6 Mo Tropical	300
#10 Kraft	1 Yr Tropical	160
#11 Kraft	2 Yr Tropical	80
#12 Kraft	3 Yr Tropical	188
#13 Kraft	5 Yr Tropical	139
#14 Kraft	5 Yr Controlled	755
#27 Nomex	None	369
#28 Nomex	5 Yr Tropical	331

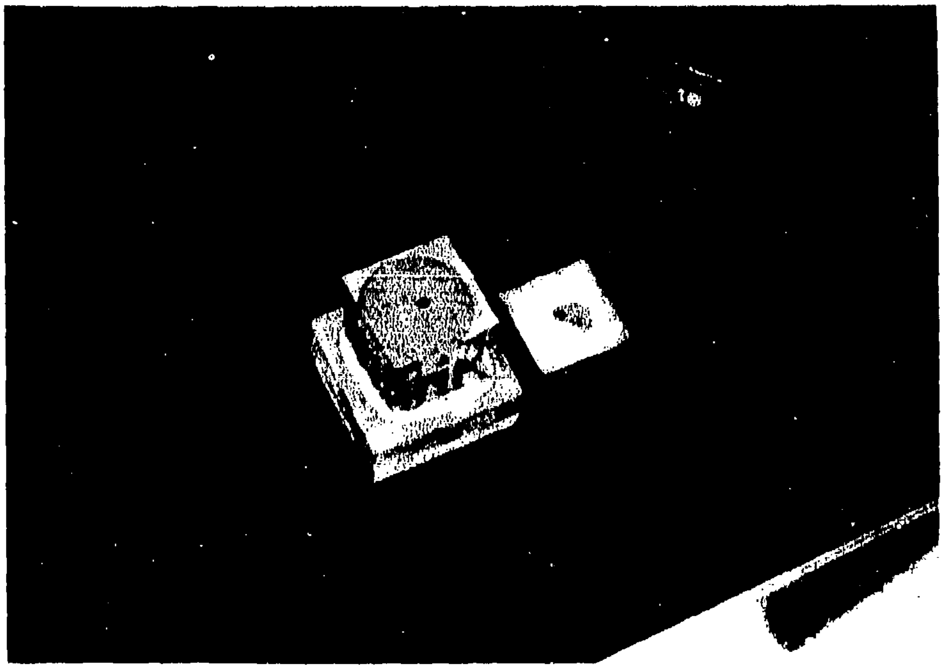


Figure 40. Repair Patch Flatwise Tension Specimen Failure Mode After 1 Year of Tropical Exposure.

have met these minimum guidelines. The beam shear values obtained for the machined specimens inadvertently stored in the controlled laboratory for 6 months were slightly lower, about 10%, than the controls and the 6-month tropical. This reduction is evident for both Kraft paper and Nomex paper cores and in both the "L" and "W" directions. After 5 years of tropical exposure, no significant change in beam shear strength was observed. A summary of the beam shear results are shown in Tables 22 to 25.

10.5 CLIMBING DRUM PEEL

Climbing drum peel test specimens were machined from each panel configuration. Except for hardware panels, each configuration is divided into quarters and six specimens are located in each of those quarters. Three of these specimens were peeled with the 0.050-inch-thick outside skin and three with the 0.040-inch-thick inside skin. Of all the tests conducted on the honeycomb sandwich panels, the climbing drum peel was the most erratic. This is partly due to the fact that the climbing drum peel test was developed using more flexible skins than either of those used in shelter roof panels. ASTM D1781, "Climbing Drum Peel Test for Adhesives," suggests using a 0.020-inch-thick skin rather than 0.040 or 0.050 inch which are used in shelter construction. There is, however, a suggested minimum value for climbing drum peel strengths in shelter panels that can be found in ASTM E874 and is 6.9 in-lb/in of width. Most all of the average values for Kraft paper core did meet this minimum value. In fact, of the 52 average Kraft paper core climbing drum values shown in Tables 26 and 27, only four values were below 6.9 in-lb/in minimum. Even though there was some scatter in the data, it does appear that after 5 years of tropical exposure, there is little effect upon the climbing drum peel properties obtained for both the 0.040-inch-inside and the 0.050-outside skins. Also of note is that the Nomex core cell size was 1/4 inch while the standard Kraft shelter core was and is 3/8 inch. The smaller cell size yields higher peel strengths because of the larger core bonding surface area afforded with the smaller cell size. This is an advantage when performing peel tests with thicker skins, at least if the failure is within the core. Since the loads are much higher, the thick skins are more likely to follow the contour of the drum. Therefore, the climbing drum peel results obtained for Nomex paper core are not only higher but there is far less scatter. A summary of the climbing drum peel results obtained are shown in Tables 26 to 29. It should be noted that the machined samples inadvertently exposed to the lab for 6 months did <u>not</u> show any decline in climbing drum strength baseline data for either Kraft or Nomex core. This was also true for flatwise tensile. For compression, the Nomex core

TABLE 22

KRAFT PAPER CORE BEAM SHEARS, "L" DIRECTION

Panel	Exposure	Avg Strength (psi)
#1 Kraft, Standard	None	225
#1 Kraft*, Standard	Machined specimens exposed to lab for 6 mos	204
#2 Kraft, Standard	6 Mo Tropical	220
#3 Kraft, Standard	1 Yr Tropical	247
#4 Kraft, Standard	2 Yr Tropical	221
#5 Kraft, Standard	3 Yr Tropical	227
#6 Kraft, Standard	5 Yr Tropical	248
#7 Kraft, Standard	5 Yr Controlled	213
#8 Kraft, Hardware	None	235
#8 Kraft*, Hardware	Machined specimens exposed to lab for 6 mos	205
#9 Kraft, Hardware	6 Mo Tropical	227
#10 Kraft, Hardware	1 Yr Tropical	240
#11 Kraft, Hardware	2 Yr Tropical	234
#12 Kraft, Hardware	3 Yr Tropical	230
#13 Kraft, Hardware	5 Yr Tropical	219
#14 Kraft, Hardware	5 Yr Controlled	235
#15 Kraft, Damaged	6 Mo Tropical	242
#16 Kraft, Damaged	1 Yr Tropical	216
#17 Kraft, Damaged	2 Yr Tropical	249
#18 Kraft, Damaged	3 Yr Tropical	217
#19 Kraft, Damaged	5 Yr Tropical	249
#20 Kraft, Damaged	5 Yr Controlled	214
#21 Kraft, No Sealant	1 Yr Tropical	251
#22 Kraft, No Sealant	2 Yr Tropical	226
#23 Kraft, No Sealant	3 Yr Tropical	234
#24 Kraft, No Sealant	5 Yr Tropical	237

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 23

KRAFT PAPER CORE BEAM SHEARS, "W" DIRECTION

Panel	Exposure	Avg Strength (psi)
#1 Kraft, Standard	None	138
#1 Kraft*, Standard	Machined specimens exposed to lab for 6 mos	121
#2 Kraft, Standard	6 Mo Tropical	129
#3 Kraft, Standard	1 Yr Tropical	149
#4 Kraft, Standard	2 Yr Tropical	134
#5 Kraft, Standard	3 Yr Tropical	133
#6 Kraft, Standard	5 Yr Tropical	144
#7 Kraft, Standard	5 Yr Controlled	118
#8 Kraft, Hardware	None	137
#8 Kraft*, Hardware	Machined specimens exposed to lab for 6 mos	120
#9 Kraft, Hardware	6 Mo Tropical	148
#10 Kraft, Hardware	1 Yr Tropical	137
#11 Kraft, Hardware	2 Yr Tropical	150
#12 Kraft, Hardware	3 Yr Tropical	157
#13 Kraft, Hardware	5 Yr Tropical	145
#14 Kraft, Hardware	5 Yr Controlled	151
#15 Kraft, Damaged	6 Mo Tropical	132
#16 Kraft, Damaged	1 Yr Tropical	130
#17 Kraft, Damaged	2 Yr Tropical	149
#18 Kraft, Damaged	3 Yr Tropical	136
#19 Kraft, Damaged	5 Yr Tropical	140
#20 Kraft, Damaged	5 Yr Controlled	140
#21 Kraft, No Sealant	1 Yr Tropical	142
#22 Kraft, No Sealant	2 Yr Tropical	128
#23 Kraft, No Sealant	3 Yr Tropical	125
#24 Kraft, No Sealant	5 Yr Tropical	146

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 24

NOMEX PAPER CORE BEAM SHEARS, "L" DIRECTION

Panel	Exposure	Avg Strength (psi)
#27 Nomex, Hardware	None	268
#27 Nomex*, Hardware	Machined specimens exposed to lab for 6 mos	250
#29 Nomex, Damaged	None	277
#29 Nomex*, Damaged	Machined specimens exposed to lab for 6 mos	263
#31 Nomex, No Sealant	1 Yr Tropical	317
#25 Nomex, Standard	2 Yr Tropical	304
#26 Nomex, Standard	5 Yr Tropical	291
#28 Nomex, Hardware	5 Yr Tropical	289
#30 Nomex, Damaged	5 Yr Tropical	284
#32 Nomex, No Sealant	5 Yr Tropical	283

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 25

NOMEX PAPER CORE BEAM SHEARS, "W" DIRECTION

Panel	Exposure	Avg Strength (psi)
#27 Nomex, Hardware	None	149
#27 Nomex*, Hardware	Machined specimens exposed to lab for 6 mos	134
#29 Nomex, Damaged	None	149
#29 Nomex*, Damaged	Machined specimens exposed to lab for 6 mos	138
#31 Nomex, No Sealant	1 Yr Tropical	168
#25 Nomex, Standard	2 Yr Tropical	158
#26 Nomex, Standard	5 Yr Tropical	157
#28 Nomex, Hardware	5 Yr Tropical	148
#30 Nomex, Damaged	5 Yr Tropical	149
#32 Nomex, No Sealant	5 Yr Tropical	151

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 26

KRAFT PAPER CORE CLIMBING DRUM PEELS, "L," INSIDE 0.040-INCH SKIN

Panel	Exposure	Avg Peel (in-lb/in)
#1 Kraft, Standard	None	12.7
#1 Kraft*, Standard	Machined specimens exposed to lab for 6 mos	10.2
#2 Kraft, Standard	6 Mo Tropical	10.7
#3 Kraft, Standard	1 Yr Tropical	10.2
#4 Kraft, Standard	2 Yr Tropical	9.0
#5 Kraft, Standard	3 Yr Tropical	9.1
#6 Kraft, Standard	5 Yr Tropical	8.9
#7 Kraft, Standard	5 Yr Controlled	11.5
#8 Kraft, Hardware	None	9.7
#8 Kraft*, Hardware	Machined specimens exposed to lab for 6 mos	12.7
#9 Kraft, Hardware	6 Mo Tropical	6.3
#10 Kraft, Hardware	1 Yr Tropical	7.4
#11 Kraft, Hardware	2 Yr Tropical	6.1
#12 Kraft, Hardware	3 Yr Tropical	6.5
#13 Kraft, Hardware	5 Yr Tropical	7.6
#14 Kraft, Hardware	5 Yr Controlled	7.9
#15 Kraft, Damaged	6 Mo Tropical	7.5
#16 Kraft, Damaged	1 Yr Tropical	7.6
#17 Kraft, Damaged	2 Yr Tropical	8.8
#18 Kraft, Damaged	3 Yr Tropical	10.1
#19 Kraft, Damaged	5 Yr Tropical	10.6
#20 Kraft, Damaged	5 Yr Controlled	7.1
#21 Kraft, No Sealant	1 Yr Tropical	12.7
#22 Kraft, No Sealant	2 Yr Tropical	10.5
#23 Kraft, No Sealant	3 Yr Tropical	12.8
#24 Kraft, No Sealant	5 Yr Tropical	10.4

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 27

KRAFT PAPER CORE CLIMBING DRUM PEELS, "L," OUTSIDE 0.050-INCH SKIN

Panel	Exposure	Avg Peel (in-lb/in)
#1 Kraft, Standard	None	9.7
#1 Kraft*, Standard	Machined specimens exposed to lab for 6 mos	11.4
#2 Kraft, Standard	6 Mo Tropical	9.9
#3 Kraft, Standard	1 Yr Tropical	14.1
#4 Kraft, Standard	2 Yr Tropical	11.9
#5 Kraft, Standard	3 Yr Tropical	10.7
#6 Kraft, Standard	5 Yr Tropical	10.6
#7 Kraft, Standard	5 Yr Controlled	10.6
#8 Kraft, Hardware	None	4.1
#8 Kraft*, Hardware	Machined specimens exposed to lab for 6 mos	9.0
#9 Kraft, Hardware	6 Mo Tropical	8.3
#10 Kraft, Hardware	1 Yr Tropical	7.1
#11 Kraft, Hardware	2 Yr Tropical	13.0
#12 Kraft, Hardware	3 Yr Tropical	10.6
#13 Kraft, Hardware	5 Yr Tropical	7.7
#14 Kraft, Hardware	5 Yr Controlled	10.4
#15 Kraft, Damaged	6 Mo Tropical	14.0
#16 Kraft, Damaged	1 Yr Tropical	15.3
#17 Kraft, Damaged	2 Yr Tropical	15.2
#18 Kraft, Damaged	3 Yr Tropical	13.8
#19 Kraft, Damaged	5 Yr Tropical	16.6
#20 Kraft, Damaged	5 Yr Controlled	15.4
#21 Kraft, No Sealant	1 Yr Tropical	9.3
#22 Kraft, No Sealant	2 Yr Tropical	13.9
#23 Kraft, No Sealant	3 Yr Tropical	11.2
#24 Kraft, No Sealant	5 Yr Tropical	7.9

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 28

NOMEX PAPER CORE CLIMBING DRUM PEELS,
"L," INSIDE 0.040-INCH SKIN

Panel	Exposure	Avg Peel (in-lb/in)
#27 Nomex, Hardware	None	14.8
#27 Nomex*, Hardware	Machined specimens exposed to lab for 6 mos	19.9
#29 Nomex, Damaged	None	19.4
#29 Nomex*, Damaged	Machined specimens exposed to lab for 6 mos	23.7
#31 Nomex, No Sealant	1 Yr Tropical	23.8
#25 Nomex, Standard	2 Yr Tropical	19.9
#26 Nomex, Standard	5 Yr Tropical	18.2
#28 Nomex, Hardware	5 Yr Tropical	12.3
#30 Nomex, Damaged	5 Yr Tropical	19.3
#32 Nomex, No Sealant	5 Yr Tropical	25.8

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

TABLE 29

NOMEX PAPER CORE CLIMBING DRUM PEELS,
"L," OUTSIDE 0.050-INCH SKIN

Panel	Exposure	Avg Peel (in-lb/in)
#27 Nomex, Hardware	None	26.0
#27 Nomex*, Hardware	Machined specimens exposed to lab for 6 mos	30.9
#29 Nomex, Damaged	None	26.5
#29 Nomex*, Damaged	Machined specimens exposed to lab for 6 mos	34.7
#31 Nomex, No Sealant	1 Yr Tropical	26.0
#25 Nomex, Standard	2 Yr Tropical	25.7
#26 Nomex, Standard	5 Yr Tropical	27.8
#28 Nomex, Hardware	5 Yr Tropical	28.6
#30 Nomex, Damaged	5 Yr Tropical	33.6
#32 Nomex, No Sealant	5 Yr Tropical	28.2

* Individual machined control test specimens were inadvertently stored in the TTC lab without plastic bag containment. Thus each specimen's honeycomb core and its bond line between the core and the specimen's skins were exposed on all four sides to lab environment.

strength was <u>not</u> affected while the Kraft core compressive strength was adversely a[illegible]cted. Also, in beam shear both Nomex and Kraft core strengths were reduced by this inadvertent 6-month lab machined specimen(s) exposure.

10.[illegible] MISCELLANEOUS RESULTS

Several tests were conducted which are identified as miscellaneous, but only because each did not generate the overwhelming quantity of data as the others. These t[illegible]ks incude insert pullout and torque. The hardware panels were received from Brunswick with inserts having been potted in specified location(s) on the green outside and white inside of each panel. Upon withdrawal, each insert was tested for pullout and [illegible]ue in accordance with MIL-S-44197A. All of the inserts passed the respective tests. Also, Shore "A" durometer was run on the polysulfide sealant on each panel upon v[illegible]hdrawal. The control and all panels up to and including 3-year tropical exposure had a Shore A durometer of 60 to 70. After 5 years tropical exposure, the Shore A durometer was 50 to 60, which is above 35 minimum specified for this Type 1, Class B sealant in [illegible]L-S-8802F, Amend. 1. The sealant on the panels in the controlled environment for 5 years had Shore A durometer readings between 60 to 70. The sealant was also visually inspected for peeling or cracking and none was found.

10.6.1 <u>Other Observations</u>

During the visual inspection of the panels at Chiva-Chiva or Fort Clayton and the specimen testing in the TTC Materials Lab, several observations were made and include:

- Some of the core splice material did not expand the full height of the core.
- When testing peel, if a core splice happened to fall within the area of peel, often the failure mode would change and the peel force would usually go down.
- The panels were constructed as roof panels, which meant each had 1.25-inch thick/1.5 lb/cubic foot polyurethane foam pressed into the core. In some panels the foam appeared to be in direct contact with the adhesive rather than 0.060 inch below the core surface as required.
- After 3 years exposure the foam in the simulated damage holes was slipping out the bottom side.

10.6.2 Results of Panel No. 32

During the 5-year tropic environment exposure, only one panel actually had moisture visible in the interior during machining. That panel was No. 32, Nomex core, no polysulfide sealant, and which was exposed to the tropical environment for 5 years. During machining water could be seen in the honeycomb core at the lower edge of the panel. Even after close examination it was not clear exactly where the water migrated through to the panel interior. The water was visible only in the lower edge of panel sections C and D. As soon as the specimens were machined, each was sealed in a plastic bag and delivered to the laboratory for test. When testing proceeded, panel 32 was the first tested. The results obtained for each test type in each quarter of the panel are shown in Table 30. The properties obtained are nearly the same in all sections of the panel and are similar to those obtained for other panels. However, this was expected since historically, it has been found that Nomex core structural properties are minimally affected by exposure to water. It is not certain how long the moisture was present in the panel. Regardless, it does show the importance of the application of polysulfide sealant to prevent water/moisture intrusion into shelter panels.

TABLE 30

RESULTS OF PANEL NO. 32, NOMEX, NO SEALANT, 5-YEAR TROPIC EXPOSURE

Section	Beam Shear, psi		Drum Peel, in-lb/in		Compression, psi	Tension, psi
	L	W	0.040	0.050		
A	282	158	29.2	26.2	557	393
B	271	152	29.8	30.3	557	427
C	296	148	23.9	25.3	612	366
D	283	145	20.3	30.9	551	411

NOTE: Moisture was visible in lower edge of "C" and "D."

SECTION 11
SUMMARY

The long-term tropic environmental exposure of rigid wall honeycomb sandwich panels performed at the U.S. Army Tropic Test Center in the Republic of Panama was a success. During the 5 years of exposure, both the Kraft paper and Nomex honeycomb panels met all the specification minimum requirements, except for some isolated individual climbing peel test results. In general, the panels performed extremely well.

The standard and hardware panels that were sealed with polysulfide sealant had an average of 0.22 pound of water pickup per panel. The unsealed panels picked up an average of 1.14 pounds of water per panel. This shows how important it is to properly seal the panels. The polysulfide sealant durometer readings were all 60-70 Shore A except for the 5-year tropical exposure readings of 50-60 which is above the 35 minimum specified for this Type 1, Class B sealant in MIL-S-8802F, Amed. 1.

Both the Kraft paper and Nomex panel flatwise tensile specimens had mainly core tearing failures. The Kraft paper honeycomb had an average strength of 425 psi while the Nomex core was 398 psi, both considerably higher than the 306 psi minimum. There did not appear to be any degradation with time. In fact, in this test and others the Kraft paper properties may have slightly increased due to further curing in the hot sun.

Climbing drum peel testing results for the standard 3/8-inch cell size 3.8 lb/ft^3 Kraft paper core panels with 0.040- and 0.050-inch 5051-H34 aluminum skins showed a lot of scatter (i.e., coefficient of variation of approximately 20 percent). The average Kraft paper climbing drum peel was 10.3 in-lbs/in. There were, however, only 4 average peel values out of the 54 average panel peel values computed where individual Kraft panel skin to core peel strength fell below the 6.9 in-lb/in minimum specified in ASTM E874. In contrast, there was little peel strength data scatter for the 1/4-inch cell size 4.0 lb/ft^3 Nomex panels with identical skins and their peel values were approximately twice as high with an average of 24 in-lbs/in. In addition, all Nomex individual panel peel data points well exceeded the 6.9 in-lbs/in minimum. The smaller 1/4-inch Nomex cell size provided more bonding surface area, thereby increasing peel strengths. It was apparent that there is a definite need to develop an alternate peel test methodology for thick panel skins (i.e., greater than 0.040-inch thick). As you go up in skin thickness the skin stiffness increases and the force required to bend the skin and lift the drum increases. Thus, your actual peel strength value becomes less and less of the total measured torque value and the accuracy and sensitivity of the measurement is compromised. Of course, bear in mind that to arrive at each panel peel strength data point the torque to bend the skin and lift the drum is subtracted from the total torque value. With 0.020-inch thick skins where the skin stiffness is much less of the total torque value measured or in cases such as with the above Nomex 1/4-inch cell size being small resulting in a high peel strength, the present climbing drum test works well and is repeatable. It should be noted that no significant decrease in peel strength values for the Kraft and Nomex core panels was indicated over the 5-year tropical exposure.

All the L and W beam shear specimens average shear strength values met their respective minimum requirements of 180 and 113 psi. Most samples exhibited good core shear mode failures. The overall average Kraft paper shear strengths were 229 psi (L) and 138 psi (W) while the Nomex honeycomb values were 283 psi and 150 psi. It should be noted that beam shear values for the Kraft and Nomex core panels essentially remained constant over the 5-year tropical exposure.

The overall average compressive strengths were 528 psi for the Kraft paper core and 552 psi for the Nomex core. Both values were much higher than the 404 psi minimum required. There was no evidence of honeycomb degradation with tropic exposure time in simulated damaged panels. The samples that had holes in just the top facing (this allowed water to be in the cells for up to 5 years) only had a slightly lower compressive strength.

The biggest deteriorations apparent were the paint coming off the zinc plated steel latches and the reduction seen in repair patch tensile strength. It was also noticed that in some samples the core splice adhesive between adjacent core sections had slumped down and was not the full 2 inch depth of the honeycomb. In contrast, generally, the core splice adhesive adjacent to the aluminum panel perimeter extrusions was fully expanded.

Over the 5 years of tropical exposure there were no panel delaminations (i.e., skin to core separations/adhesive film bond failures) and the structural properties of both the Nomex and Kraft paper cores did not degrade. In summary, if the panels are manufactured in accordance with ASTM E864, E865, E866, E874, E990, and E1091, and sealed with Type 1, Class B polysulfide sealant per MIL-S-8802, either the Kraft paper or Nomex panels should perform very well in a hot-humid climate.

U.S. GOVERNMENT PRINTING OFFICE 750-113